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EUROPEAN SEWAGE AND GARBAGE REMOVAL.

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I do not pretend to treat this subject at all exhaustively—as handled by Mr. R. Hering, M. Am. Soc. C. E., in his report to the National Board of Health in 1881, or by Mr. S. M. Gray, M. Am. Soc. C. E., in his report of 1884 to the City of Providence--but will give the Members of the Society the aspect of the subject which has presented itself to me during a somewhat prolonged stay in England and on the Continent, together with some remarks on the application of European principles to our own sewerage.

The accepted methods of handling sewage in vogue in Europe at present, and which have proved themselves more or less satisfactory by use during a term of years, are, generally speaking, five in number:

First.—The removal by wagon from privy-vaults directly to land which is fertilized by it.

Second.—Removal by water in underground sewers to the nearest river, or to the sea; the oldest and simplest of the more perfect ways of disposing of the sewage.

Third.—Removal by the same means to a neighboring river, with the interposition of works for the purpose of sufficiently purifying the sewage to render it inoffensive in the stream to which it is delivered while passing through the open country, or through lower-lying towns and villages.

Fourth.—Removal, as in the last two, to an area of land, over which it is discharged, and by the filtering or deoxidizing action of which, and of the plants thereon, it is purified before discharge into a convenient water-course.

Fifth.—Removal of the sewage in an undiluted or very slightly diluted condition to purifying works, where it is wholly or partially converted into high grade and inoffensive manures.

The first method is the primitive one, and still obtains in its most primitive form for the vast majority of the town and even of the city populations of Continental Europe; and for a large fraction besides in the cesspool form, the contents being removed by pneumatic process. The fecal matter is carried into the adjoining country by whole processions of long casks on wheels, and the roads adjoining European cities are rendered sweetly odorous by these fragrant caravans. This method may be said to prevail throughout all Germany, except in a few cities; such cities as Dresden and Munich being still largely treated in this way. The notable exceptions within my knowledge are Berlin, Hamburg, Frankfort-on-the-Main and Dantzic. Hamburg was among the earliest cities in the world to adopt the second method, and consequently the great majority of all the houses have water-closets.

The second method grew naturally from the covering in of the open water-courses and the provision of an ample pressure water supply. The water-closet then enabled the sewage to reach the nearest considerable stream through these covered water-courses cheaply, and not too offensively for immediate endurance. The stream then carried it off, and, if rapid enough, soon purified the sewage, so that it was no longer offensive—at least to the smell. This system found its way, therefore, almost contemporaneously with the introduction of a pressure water supply. Whether the Romans had any sort of water-closets is not known, but they used the second method largely in some form, and all the large cities of Europe have it to a greater or less extent.

The increase of population and the sluggishness of the rivers in Holland and parts of England, soon made the discharge into rivers a

nuisance to some extent, and brought about government interference, obliging the cities using the second method to modify it in some way to avoid polluting the rivers. This was done in London by its great intercepting sewers carrying the sewage down the river to what was considered a sufficient distance to avoid a nuisance to London itself, or to the large towns below it on the river. This, however, proved only a makeshift, as the pollution increased in a double ratio: first, from the increase of the sewage itself; and secondly, from the removal of the water of the Thames above the city for its water supply, thus diminishing the flushing power of the stream to a serious extent in dry seasons. How far this is true may be seen from some recent experiments with a new method of observing the rate of movement of sewage (by Mr. R. W. Birch), reported in *Engineering*, May 23d, 1884, in which he states, as the result of his experiments, that the sewage discharged into the Thames at Barking remains in the river during heavy floods for twelve days, and in dry weather thirty-two to thirty-three days. So the sewage of four to five millions of people for a month is generally to be found distributed along the river from Barking to its mouth, a distance of about thirty miles, averaging perhaps two miles in width, and, of course, much more concentrated at the upper end than below. As in the meantime the stuff is carried backward and forward in the estuary for about a month, a large part of the solids must become incorporated with the mud-flats, although the river conservancy has as yet made no complaint of silting up from this cause. The question of an extension of the intercepting sewers to some point nearer the sea, and of extending them upwards along the river to help out the towns above, which are now shut out from the use of the river as a sewer, is much mooted.

Large cities like Leeds, Manchester and Birmingham, lying on small rivers, and further from the sea, have been already forced to adopt other means of disposing of their sewage. Leeds and Birmingham have adhered to the water carriage system, but have resorted to artificial purification methods, of which they have tried a variety, but all unsuccessfully as far as the production of a manure salable for more than the cost of producing it is concerned. They have, therefore, abandoned for the present the attempt to produce a salable manure, and Leeds contents itself with precipitating the solids and neutralizing the liquids with milk of lime. The result is so far successful that the water delivered to the Aire is as clear and inodorous as that of any ordinary country

brook, and is without color, except when the dye-works of the city are in full operation. At such times it remains transparent and odorless, but has a very perceptible color. The defective feature of the process is the accumulation of sludge, which is only valuable as manure on very rank lands, and consequently finds a very indifferent sale. It is found, however, at Leeds that the farmers will remove it from the works if given away, and its disposal is therefore provided for, if the idea of profit from it be abandoned.

It is also claimed that the apparently inoffensive effluent will become again putrescent if discharged into a sluggish stream where its progress to the sea is slow.

The cost of the process to the city in 1884, including pumping, was $24 700. As the works cost $287 720—including part of experimental works no longer used—there is, at 5 per cent., an interest charge of $14 386, or a total annual cost of $39 086 for all expenses of taking the water from the intercepting sewer and returning it to the effluent conduit in a clear and inodorous condition. In 1884 the feces of 176 334 people were removed and purified at the above cost, making the cost per head per annum 22 cents; and of removal of dry privy matter the cost was, in 1879, for Leeds 24 cents per head per annum. The latter includes the removal of ashes, rubbish and garbage.

This, of course, does not fairly represent the matter, as the dwellings of 305 324, of the total population of 327 324, lay in the sewered district, and probably the vast majority of these discharged their slops into the sewers, causing nearly as much expense to the wet carriage system as if they had discharged fecal matter as well into the drains; and the sewers served also for surface and ground-water drainage. If the present cost of the wet carriage provided for all the sewage of the 305 324 served by it, the cost per head would be reduced to 13 cents, and it is safe to say that this would not be increased more than 25 per cent. by the increased service, or to say 16 cents, only about 66 per cent. of the cost of removal of dry excreta with the ashes and garbage, but without the slops or the purification of the latter. I have omitted in this calculation interest on the cost of the sewers themselves, or the cost of maintenance of the same, because these sewers are required at any rate for slops and surface and ground-water, and their use for fecal matters is only a convenience and part of the advantage of that system, and not justly chargeable to it. Practically, the same expenditure would be required for the sewers when dry removal is practiced.

It therefore appears that however expensive such purification processes may appear for large cities, there is a large margin of expense over the cost of dry removal with which to meet the removal of rubbish and garbage, even if future improvements do not make the sludge salable as manure. This too, apart from the immense advantage to health of the immediate removal by water.*

The details of precipitation, as practiced at the Knostrop works of the Leeds Corporation, which are a model of neatness both externally and internally, are as follows:

The sewage, on entering the grounds of the purification works, is passed through an open well with a grating in it, which intercepts all floating material. It then passes directly to the pump-well, into which the milk of lime used as a precipitant is run in a steady and continuous stream, in quantity determined by tests taken at regular intervals of the effluent quality. The sewage is dammed into the pump-well up to a certain height by a sluice. When its quantity exceeds a certain amount it overflows directly into the river, and at such times purification is suspended, as the sewage is too dilute to make it necessary. The pumps, which are Gwynn centrifugals, raise the sewage mixed with the lime 18 feet, and deliver it directly into the settling tanks by a circular main 3 feet in diameter. There are three pumps, each having a capacity of thirteen million gallons in twenty-four hours with the above lift. Two of them are generally kept in operation. In dry weather one pump working twenty hours does the work. The minimum flow from the city is nine million gallons per day. In heavy rains it rises to one hundred and ten millions or more, which must be somewhere near the capacity of the outfall, which is 8 feet high by 7 feet 9 inches wide, with a fall of 1 in 1 634.

The latter will therefore serve an enormously larger population than the present one, by using overflows from the intercepting sewer. It has also been proposed to diminish the amount of pumping required by building high level intercepting sewers to take the sewage from the upper parts of the town directly to the settling tanks.

The milk of lime used consumes 126 tons of lime monthly, and is made with enough water to run very freely. It is mixed in circular vats

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* To get at the actual annual cost of the Leeds sewerage system per capita, 5 per cent. interest on the $1 892 280, which the sewers have cost, or $94 614, and maintenance cost of sewers proper of $4 000, must be added, making a total of $137 700 per annum for the removal of the water-borne sewage and storm water, and the purification of the same for the population of the sewered district (305 324 people), or 45 cents per head.

with vertical revolving stirring shafts, with horizontal arms, and is delivered from the mixing vats directly into the pump-well, which has been found the most satisfactory way—the first process, of delivering into the pump inlets, where it was agitated by a mechanical stirrer, not having proved of practical advantage.

A 20 horse-power engine serves for lime mixing, and for hoisting of water and materials. The lime has suitable storehouses and slaking bins provided, and a railroad siding gives ready access for supplies.

The 3-foot main above mentioned discharges into an open channel, with six tanks on either side. This channel has cross-gates at the division lines between the tanks, and also into each tank; and the tanks can also be cut off from each other by flash boards, so that the sewage can be directed in any desired course through the tanks, and into and out of the main channel. Thus any tank can be cut out of circuit for cleaning, while the sewage takes its usual course through the others, passing around the empty one through the main channel. Eleven of the tanks are 100 feet in length along the channel, and 60 feet at right angles to it; the twelfth being only 88 feet long and of the same width as the others. The tanks have concrete foundations, clay puddle walls and floors, and are paved, sides and bottoms, with stone.

The regular course of the sewage is into the first tank to the right of the channel, and from tank to tank over brick partition walls, capped with stone, into the sixth on the right, whence it crosses and returns from the sixth to the first on the left in the same way. The first on the left, or No. 12, has an outlet weir, over which the sewage flow is regularly gauged. After the tanks had been arranged as above, it was thought best to utilize five acres of adjoining land by converting it into a final settling basin before letting the effluent go, when the sewage seemed to need any additional purification. To do this, and at the same time not to interfere with the weir action, the late Mr. Morant,* Borough Engineer, devised an ingenious trough sluice. This is a rectangular structure, closed at one end, built of boiler plate and angle irons, and running on rollers over the waste way.

By racks and pinions it can be moved under the lip of the weir by an attendant in one minute, when the effluent is discharged into the

*I am indebted to the reports of Mr. Morant and of Mr. Hewson, the present Borough Engineer, and to notes furnished kindly by the latter, for such information as I did not get from personal observation.

auxiliary reservoir. When moved away, which is done with equal readiness, the water flows freely into the waste-way.

A good current through the tanks is obtained by dropping each division wall two inches below the preceding one; and to prevent the fresh sewage from running in a thin sheet over the stagnant water in the tanks —found to be a source of imperfect action at first—the third and seventh tanks contain cross walls built to the full height of the sides, and with openings at the bottom, by which the sewage is forced downwards, and the onward movement of the whole body of liquid maintained. Beneath the center channel is a subway 6 feet wide by 5 feet 8 inches high. In this is a cast-iron pipe, 18 inches in diameter, with 12-inch branches to each tank, provided with gates placed in the tanks at the level to which sludge is allowed to rise. For cleaning any tank it is cut out of the circuit, and the liquid is drained through the above gates and carried back to the pump-pit. This done, a 24-inch gate at the lowest corner of the tank is opened, and the sludge is swept through it and a pipe in the subway to a pump-well, whence it is raised 16 feet to a movable chute, which delivers it to the drying ground, where, according to the present process, it remains until removed by any one who wants it.

The twelve tanks have a united area of 71 270 square feet and contain two and a half million gallons. The smell from them is very slight, the strongest smell about the premises being in the pump-room, where it is by no means unbearable. The first five tanks are cleaned every five days, and the sixth and seventh about once a week. The remaining tanks seldom require cleaning, the deposit being never over an inch. They are emptied four or five times a year, to change the water effectually. When ready for cleaning, the mud in No. 1 averages 21 inches deep; in No. 2, 18 inches; No. 3, 10 inches; No. 4, 6 inches; No. 5, 5 inches; No. 6, 4 inches.

In the elaborate works on this system now in progress for Frankfort-on-the-Main, designed by Mr. W. H. Lindley, the distinguished successor to his father's reputation in this department, the sewage is divided over the whole precipitation space, entering three tanks, comprising the whole area, at once, instead of passing in succession from one to another. This process gives a slower velocity to the sewage than the other; which, if attained, will probably be more advantageous. It seems probable however, that some measures will have to be taken to prevent the surface flow referred to above, no provision being as yet

made against this in the Frankfort works. It can be readily introduced afterwards if found necessary. Four tanks are provided, as one is always liable to be in process of cleaning. Mr. Lindley has been able to so arrange his levels, by taking advantage of the rapid fall of the Main, in putting his works some distance below the city, that it will only be necessary to pump the sewage in times of excessive flood, and for the purpose also of emptying the basins to be cleaned.

The expense of the Frankfort works has been considerably added to by the assumed necessity of vaulting over the basins on account of interference with cleansing by ice formation. It would seem not impracticable to use scrapers for dragging the sludge to the sludge pumps, operable under the ice by machine power.

At Frankfort it is proposed to use as a precipitant chiefly sulphate of alumina, in the form of alumino-ferric. The effect is as follows: The acid of the alumino-ferric is set free by its reaction with the alkaline matters in the sewage, and the alumina, through its affinity for the organic substances in solution, precipitates the latter in solid form. As the alkalies in the sewage are not sufficient to neutralize all the acid in the sulphate, enough lime is added to render the whole action of the alumina available. Where a great deal of acid is contained in the sewage, as where certain manufactures and dyeing processes are carried on, as much lime is needed for this process as would suffice for the entire precipitation, hence it is not practicable.

Its advantages, when practicable, are, as given by Mr. Lindley, to whom I am indebted for many courtesies:

First.—It precipitates impurities in solution as well as those suspended.

Second.—Its effluent is not so liable to after-putrefaction.

Third.—It does not make so much sludge as the lime process.

Fourth.—There is less danger of the escape of free lime in the effluent.

The smaller towns, which were favorably situated for the purpose, made use of simple irrigation for purifying their sewage with success, and I think there is little doubt that this is the best solution of the question for smaller inland places.

The entirely favorable conditions are that the place shall lie high enough to give a natural drainage into irrigation ground also lying high enough to be drained by subsoil drains at least five feet below the surface.

The process can be applied by pumping the sewage when the town lies too low to fulfill these conditions. The depth of drains for the irrigation ground is determined somewhat by climatic conditions. The town of Harrogate, in Yorkshire, England, with a population of about ten thousand is a good illustration of the sewage broad irrigation process. It has an exceptionally favorable situation, lying very high, and with its sewage farm in the immediate outskirts, also lying high enough to receive the sewage over almost its whole area, and at the same time with slopes steep enough to cause a rapid circulation and rapid drainage. The ground used is about two hundred and thirty acres, upon which is delivered the whole of the sewage and a part of the storm water as well. At ordinary times the sewage is satisfactorily purified (the effluent is not entirely inodorous) before reaching the drains, which are four feet underground. In dry weather, however, when the ground cracks, the effluent is unsatisfactory, and the authorities are of the opinion that the drains should have been placed six feet deep instead of four. As this is in the moist English climate, it appears certain that with land as sloping as this (averaging about 1 in 14 to 1 in 16, from my recollection), in the American climate the drains could not safely be put less than five feet deep, and probably six to seven would be expedient. If, on the other hand, flatter land be used, the drains might be at less depth, but more land would be required.

In this connection a curious fact is of interest. The sewage as it reaches the farm, after running perhaps half a mile from the thickly settled part of the town, comes out simply as a turbid stream, and leaves no undissolved constituents like paper after soaking into the ground. On an occasion, however, when the sewer was broken in the immediate vicinity of the town, the ground in the neighborhood was covered with paper. The town authorities deduce from this that all the matters going into the sewers are dissolved or ground up in the passage, but it appears to me more probable that a silting process is going on in the sewers, which was to some extent interfered with and remedied by the break, which was, I believe, caused by a flood in the adjoining stream. At this time it might be presumed that an unusual body of water was passing through the sewers, though they are not to any great extent the carriers for the storm-water, which is otherwise provided for. In long water carriage the paper and other matters do undoubtedly lose consistency, but half a mile is too short a

transport to account for the difference between an undissolved condition, and entire disappearance of these matters.

The description of the Harrogate system will show the difficulty of introducing it for cities of 100 000 or more. If we could find land equally favorable in its neighborhood, a city of 100 000 would require on the same basis not less than 2 000 acres for irrigation.* As the system involves deep sub-drainage, and at least partial control of the way in which the sewage is laid on, which must be done with regard to purification, rather than to production of crops, it becomes apparent that the system would be expensive in first cost, and a very cumbrous one to handle. This will be still more evident, since the area required for 100 000 people would generally be far more than the 2 000 acres of the exceptionally favorable Harrogate basis, even with artificial elevation of the sewage, and could not be found in one compact body, but must be selected in several places, more or less remote from each other. This because the flatter area, while more perfectly purifying the sewage, becomes more easily flooded and unfavorable for cultivation.

At Harrogate the sewage farm is worked by the city, and proves fairly remunerative for the capital put into it, but it is not used as a Poor Farm, with which it might generally be combined in our towns of a similar grade.

Features favorable to irrigation in the United States are, first, the ameliorating effect on frost in the ground of the winter flow, which experience shows to be of such high temperature as to have a decided thawing effect; and secondly, the dryness of our summers, which would make the advantage of irrigation greater in that season.

A modification of irrigation, for the purpose of reducing the area required, is the filtration method, suggested by Dr. Frankland in 1870, and first practiced by Mr. Bailey Denton immediately afterwards. The land occupied, instead of being simply sub-drained, is first chosen with regard to its porous character—chalky or sandy soil is best—and its favorable levels. It is then divided into four plats of equal area inclosed by low embankments, upon which the sewage is discharged in succession for equal periods of six hours each.

The accepted minimum area for this method of purification is one acre to 1 000 persons, and the sewage of the town of Kendal, Westmore-

* One thousand has been thought sufficient by some competent authorities.

land, with 10 000 people, has been purified on this plan for about ten years with 850 people per acre, the effluent being clear and inodorous to the present time.

Certain kinds of crops can be raised on this land, but a profit is not expected from it, and where the sewage is discharged upon it in a crude state, it seems a question of limited time only when it shall become too much choked with sludge to work efficiently. It is now generally recommended for large places only in combination with preliminary precipitation, as in the report for 1884 of the English "Royal Commission on Metropolitan Sewage Discharge," where it is proposed to establish precipitation works at the present outfall of the London sewerage at Barking, and to discharge the effluent over a filtration area, from which it will be presumably again discharged into the Thames; though the Commissioners are rather vague upon this point, and indeed appear to have gone but little into the details of the scheme, which involves acquiring not less than 3 500 acres of land of suitable quality, from which little or no return can be expected, and which must be prepared at an average cost of $350 per acre,* the land itself, if obtained within a reasonable distance, costing at least $1 000 an acre. On this basis 3 500 acres would cost, ready for operation, about five million dollars, with only a moderate allowance for a conduit to the filtering ground. The interest on this at five per cent. would be $250 000, and allowing the cost of maintenance as $3 000, the annual cost per capita for 5 000-000 people would be five cents. Adding this to the sixteen cents which we allowed for Leeds precipitation, we have a total of twenty-one cents per head per annum. Now it is clear that the cost of carrying a sewer out into deep water of the English Channel would not be more than $500 000 per mile, as numerous railway tunnels over a mile in length have been built for this figure,† or $22 500 000 for forty-five miles, including submarine outlet three miles in length. The interest on this at five per cent. would be $1 125 000. The total annual cost of this per head of a present population of 6 000 000 in the Thames Valley would be 18.8 cents, allowing for maintenance, say nineteen cents. To this must be added eight cents per head for pumping to place it on the same basis with the filtration estimate, and we get twenty-seven cents per head against twenty-one cents for filtration.

* Average of Mr. Bailey Denton's experience.

† The last great tunnel, the Arlberg, in Austria, cost $813 000 per mile for 6¾ miles.

If now it is considered that the above cost of the outfall to the sea would probably cover a conduit for a future population of ten millions—or if not, could be made to for a slight additional percentage—the cost per head for that population would be, say, 12 cents for construction and maintenance, and 8 cents for pumping, or a total of 20 cents, against 21 cents by filtration. This last figure does not entirely represent the figure for increased population, for a suitable increase of land could probably only be had at a greater proportional expense, while other expenses would rise proportionately to the increase of population.

It is also to be considered that some return might be expected, as time went on, for supplying irrigation water to lands adjoining the conduit to the sea.

From this comparison I conclude that it would be more profitable for London to extend its intercepting sewer into the ocean, where the purification is always certain, if the sewage is discharged at a sufficient distance from the shore, which distance need never exceed a practicable amount.

Recent experiments on the effect of dilute sewage on fish indicate that even those generally supposed to live only in perfectly pure water flourish better where some organic matter is carried, and that a stream or body of water in which the percentage of sewage does not exceed a certain limit will support more fish than where it is absent. If this result is confirmed, it would be a still further argument for the discharge of sewage into large bodies of water in which this interesting means of converting sewage into food exists.

Owing to the element of uncertainty how long a filtration area will remain available, it seems to me a matter of much serious consideration whether filtration without preliminary precipitation is at all practicable for cities too large for irrigation, and too distant from a large body of water for direct discharge into the same.

The fifth method, in its simplest form, is practiced on a larger scale than anywhere else in Manchester, England, where the excrement, solid and liquid, is deposited in pails, into which are placed at irregular intervals—usually daily—the house ashes, with the object, attained partially at least, of deodorization. These pails, fitted with air-tight covers, are removed twice a week or oftener to a depot in the outskirts of the city, where by a variety of processes, chemical and mechanical, the refuse of the city, including the market garbage and dead animals,

as well as the feces, is converted chiefly into a high grade manure, sold at £3 per ton delivered within 150 miles of the city, and otherwise into a great variety of materials like mortar, soap, oil and candles, all of which, except the mortar, are used up by the city itself. I have not been able to get very satisfactory pecuniary statistics as to this process. So far as it appears from documents available to me, the cost of disposing of the dry closet refuse and garbage for the city for the year ending March 31st, 1882, was $185 460. This seems to have been the gross cost before deducting sale of mortar and manure. Sales of 7 000 tons of manure, say at $13.50 net, give $94 500; 9 368 tons of mortar at $1.25, equal $11 710; total, $106 210; leaving, as the net cost of the establishment, $79 250, less an uncertain amount for other products of the sewage used by the corporation. The cost of the works was $600 000. Interest at 5 per cent. is $30 000, or a total annual cost to the city of $109 250. If this dry removal cost the same per head as at Leeds, it would amount to $70 800, leaving $38 450 to be accounted for by the other products of the sewage, or by excess of cost over the Leeds dry removal.

Now the population of Manchester is 350 000. There are 11 000 water-closets. I assume five persons to a water-closet. This is probably not too small, since they are largely used by a day business population of 150 000, which is additional to the resident 350 000. Taking out then 55 000 served by water-closets, we have 295 000 using dry-closets, giving for a total annual cost as above of $109 250, an annual per capita of 37 cents. As this, however, covers garbage and ash removal for the population using water-closets as well as those served by dry-closets, the only deduction that can be made from the above figures is that the cost of dry removal of feces and garbage in Manchester is probably somewhere between the Leeds figure of 24 cents and the 37 cents above found. The advantage gained by the extra expense, if the cost is any greater, lies in the rapid removal of the putrescent matters from the premises instead of keeping them for long periods in vaults. It is to be noted that the above per capita includes not only, as in Leeds, the carting of dust and refuse, but also the cost of getting rid of dead animals and other organic refuse by destructors, an item which I have been unable to separate from the other expenses.

The Liernur separate system, when conducted in its best form, costs for actual running expenses 22 cents per head of population served, ex-

clusive of interest on plant and dust and garbage collection;* so it is evident there is no material advantage, if any, in the latter on the side of economy, and it is probably considerably more expensive than either well conducted dry removal or the combined wet-carriage system.

In summing up the conclusions to be drawn from European systems, I think it safe to say that dry carriage can under no conditions be either economical or healthful, though it may be made, as it has been in Manchester, a great amelioration of the old privy system.

In general the combined system of wet carriage seems expedient for closely built cities or quarters of the same. This statement supposes sizes of branch sewers large enough to carry the sewage and to clear the streets of ordinary rains, and the provision of overflows for interceptors such that the latter shall not be weighted with more water than is desirable to carry the sewage proper and to clean them.

The separate system finds its natural adoption where the slopes of a city are so steep, or the town sufficiently rural, and likely to remain so, as to make it practicable to carry the storm-water by open gutters into natural water-courses. This applies to parts of cities and towns as well as to the whole. Thus a city might be advantageously provided with the combined system in a flat business portion, while steep streets in a dwelling quarter could have drains for sewage alone. In a city where combined sewerage is used, however, it would generally be undesirable to adopt a separate system for a dwelling quarter merely on account of thin population, when topographical reasons were absent; since the rapid alteration in the character of cities, particularly in the United States, makes the present character of a city district of little value in determining its drainage system.

Toledo

As to the disposal of the sewage. If a city is near the sea or a great lake, I have no hesitation in saying that those bodies of water are the natural receptacles of the sewage.

This can be discharged in a small town on the shore of a body of water directly into the same at any convenient number of points, with such disposition of grades, however, as to allow eventual intercepting sewers with a single outfall.

The latter could be extended further into the sea or lake as the city increased in size; or, if the character and thinness of the coast settlement admitted it, be carried some distance along the shore, as at Brighton,

* See Hering on Amsterdam sewerage in 1880.

England, and carried further away as became necessary. Such prolongation of an outfall beyond a limited distance would, of course, generally involve pumping to give discharge head.

Where direct discharge into a sufficiently large body of water is inadmissible, irrigation is the first method expedient. It is generally limited only by the size of the city, since pumping makes the attainment of a suitable area for the same always possible where the town is unfavorably situated for direct discharge over an irrigation area.

As the city found its irrigation becoming unwieldy, or the acquirement of land too expensive, recourse could be had to preliminary purification prior to irrigation, which could then become filtration in part, and more and more as the amount to be disposed of increased. Berlin is fully launched in the first stage of this process. Whether it is feeling at all pressed towards preliminary purification can probably not be known by the outsider, but it may be fairly assumed that even the 13 222 acres owned by it in 1884 as an irrigation farm will before long be fully occupied in handling the rapidly increasing population of the German metropolis, even with the partial use of filtration already introduced.

It is impossible, however, to lay down hard and fast rules to fit all cases. Dantzic, whose sewage farm lies directly on the sea—the city itself being not far distant—was clearly right in adopting irrigation, since it was able to obtain an area of but little more value than beach sand, which its sewage on the way to the sea has converted into a profitable farm, whose products pay the entire cost of pumping and of the maintenance of the sewerage system.

The City of Providence, under Mr. Gray's advice, declines to irrigate, because, although the body of water near it is too small to admit direct discharge, it is large enough to take purified sewage at less expense than would be caused by pumping to distant irrigation fields, only to be found at a pretty high level.

Boston has wisely chosen the sea discharge, and New York and the neighboring cities will probably have to do the same at some future day, though their exceptionally favorable situation may postpone it some time. Chicago, if I am not mistaken, will find discharge into the lake several miles out, the solution of its difficulty. Discharge rearward into the Desplaines River cannot be long endured by the population along that and the Illinois River. In regard to the dwellers on the Mississippi who congratulate themselves on the possession of a sewer outfall with

infinite dilution capacities, I think it can only be a matter of time when preliminary precipitation must be resorted to, to avoid the nuisance caused by the deposit of filth along the banks and bars of the great river, and the injury to the drinking water drawn from it, though the time may be distant.

European sewage depends too much on hand leaning. Sewers should, of course, be inspected regularly, but a well arranged system of sewage should, with little exception, clean itself, either by its normal flow, aided by rains, or by automatic flushing with ground or other water. To do this with certainty it is necessary either that the grades should be so laid that no diminution of velocity ever takes place at any point in the sewage system, or that no particles shall ever enter which will not be carried by the least current velocity found anywhere. The former condition is generally impossible. As to sewage and slops, the latter condition can be generally, if not always, attained by the passage of the kitchen slops through grease-traps, after which the tendency of the fermenting sewage will be more and more to float without adhering to the sewer walls. Things thrown into the closets of a house will almost always float if they will pass the traps at all.

The latter should, of course, always be capable of being cleaned. Street washings are the greatest source of heavy deposits, and to attain the desired object we must prevent the entrance of particles too heavy to be held suspended at the minimum current velocity. For this purpose our old fashioned street basin, trapped by a dipping apron, is a more rational scheme than the various arrangements which have come into vogue in Europe, which either pass the street washings directly into the sewers, as at Paris, and involve most systematic and expensive cleaning, or else only very partially catch the washings in a small removable pot at the bottom of the little catch-basin used. The latter is generally covered by a grating which becomes stopped up by the paper, straw, leaves, etc., washed off the street in a heavy rain, and is highly successful in flooding the street around; and the velocity of the water passing through the basin is so great, that only the very heaviest particles are left in it. All this might be avoided by a combination of the three arrangements. In the first place the discharge from the street should be sideways through the curb (if in one direction only) and without a grate, so that the floating stuff could be carried into the basin where it belongs, and not stop the inlet. Secondly, to prevent the floating stuff getting into the outlet or

passing into the sewer, there should be a diaphragm across the catch-basin, dropping below the bottom of the outlet and rising close to the cover of the basin to catch this floating matter and to oblige all the entering water to take a downward direction. This should not, of course, close the basin at the top, but should allow free circulation of air to the sewer. The size of the basin should be so regulated that the diaphragm could be placed at such a distance from the outlet that the water in reaching the latter when fully filled, should have no greater velocity than the minimum maintained in its after passage through the sewers. The basin velocity could generally be reduced to one-half the after minimum without making the basin of excessive size. This would cause the precipitation of all the heavy particles from the street water into the bottom of the basin, which should be fitted with a removable receiver. The diaphragm being made removable also, the receiver could be hoisted out by a derrick attached to the rear of a wagon, and the contents discharged into the latter. The sectional area of the catch-basin on the inlet side of the diaphragm should be arranged so as to afford sufficient room for floating matters without causing such a velocity of the inflowing water that they would be sucked under the partition.

It is difficult to see, under such a system, how any material could stop in the sewers themselves, and certainly nothing whose presence could foul the sewer in the interval between hard, flushing rains. The possible escape of substances of a bulky nature under the diaphragm and into the outlet of the basin could be prevented by a grating over the latter.

That the deposition of sediment in sewers depends almost entirely on such regulation of velocities, is shown by the experience with the numerous siphons under the river channels in Dantzic. The siphons are provided with a basin at the entrance arranged on the above principle. The sewage falls upon a horizontal apron and passes with very slow velocity to the mouth of the siphon, with the result that in fourteen years use these siphons have never required cleaning, all floating matters being caught on the apron and heavy ones being dropped into the bottom of the basin.

The more usual practice as to overflows in Europe is to place them practically at the top of the sewer. In view of the fact that matters in the sewage not yet reduced to solution or to very fine comminution generally float, a better arrangement of the overflow would be a long narrow opening at the lowest point at which the sewage was considered

diluted enough to permit it to overflow. The opening could be made narrower than called for by weir action, the head of pressure above it giving a larger discharge. The effect of this would be to allow the escape of the foulest sewage only at such time (generally short) when the quantity flowing was constant and just filled the sewer to the overflow point. Above that level the floating matters would overrun the overflow, the water below being tapped off. Such an opening might be screened also with wire netting, since the scouring action of the current along the sewer would clear it of such material as did not force its way through.

An ingenious arrangement has been devised by Mr. Hewson, the Borough Engineer of Leeds, for letting off the overflow somewhat as recommended above, but with the additional feature of a gate closing the main in proportion as the overflow carries off the water. The apparatus is as shown in the cut, Figs. 1 and 2, Plate LXXXVII. The sewer (presumably a branch about to enter the interceptor, or it may be the interceptor itself), enters a chamber rectangular in plan. The invert is carried unbroken through the chamber into an outlet in line with the sewer whose surplus is to be carried off. This outlet is considerably smaller than the sewer it serves, being intended to carry only the sewage proper, with a certain allowance of dilution, into the interceptor, or into the sewer continued,

On one side of the above chamber is the outlet for the flood water. This is shut off during the normal flow of the sewage by a box, either of wood or metal, forming one side of the sewer. This box moves up and down in grooves in the chamber walls, and is connected by a chain and sheaves to a gate across the outlet of the sewer proper, in such a manner that when the box is in a closed position, forming one side of the sewer, the gate is wide open. As soon as the flow increases above a certain level in the sewer, the box floats up and allows the sewage to run off below it, at the same time partially closing the regular outlet. Eventually, in a heavy flood, the regular outlet would be entirely closed and the entire flow would pass through the overflow. This overflow offers a considerable advantage in opening always below the water level, and in adjusting its opening to the water to be passed through. The advantage of the gate across the regular outlet lies therein, that when it is closed the whole capacity of the sewer beyond this outlet will be called for in carrying the local storm water, and by the use of such gates the

Automatic Overflow, Leeds Sewerage

PLATE LXXXVII
TRANS. AM. SOC. CIV. ENG'RS.
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WHITE ON EUROPEAN
SEWAGE AND GARBAGE REMOVAL.

FIG. I.
PLAN

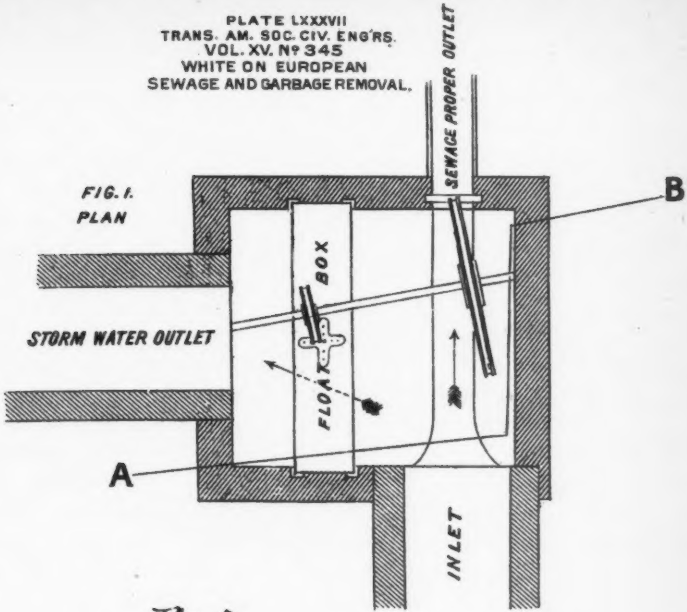
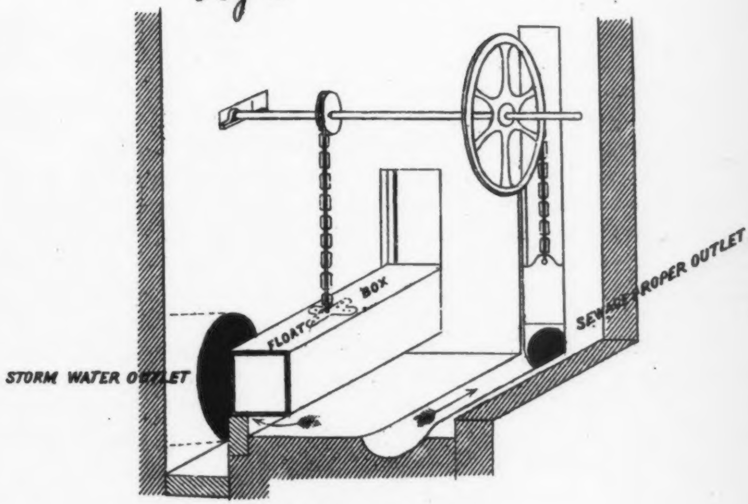


Fig 2.



SECTION A.B

intercepting sewers might be made little, if any, larger than called for by the normal sewage flow.

Of the practical working of these gates I have no particulars, and their advantages largely depend upon how much they can be trusted to operate infallibly.

Mr. Hering recommends in his report, overflows in the line of the sewer; the latter being deflected at this point. Apart from the accumulation of any bulky matters which might be passing through at such points, such a position would certainly lead to the discharge of the matters most desirable to keep in the sewer.

Sewers which have to be made large enough to enter could be made with advantage, and at small expense, large enough to carry the water-pipes and electric wires, and even gas-pipes when the sewers are thoroughly ventilated at the top of the same. The size should be such that, except in extreme rains, repairing operations on pipes, etc., could be carried on by floats made for the purpose, or on portable platforms. The expense of such enlargement would be small compared with the saving of street upheaval and interruption, and in view of the readiness of repairs at almost all times.

There is one matter of ventilation in which I think European systems are generally wrong, while the American ones are, to my mind, not entirely right. Many or most European cities ventilate sewers partially through house soil pipes; we, on the contrary, with few exceptions, and rightly I believe, cut off the sewer from the houses by traps.

In explaining where I believe our practice is wrong, I will begin by inquiring what the object of ventilation is, for this object seems to me to have become partly obscured under the word ventilation, which has here a somewhat different meaning from its usual one. In sewers large enough to enter, the object is to keep the sewer air pure enough to breathe without danger, and to avoid having it enter the living rooms of our houses, no matter how good its condition. In sewers too small to enter, the latter object is the sole one, and this applies to house drains.

First.—The object of house-drain ventilation is often stated as the greatest purity of the air of the drains and pipes. Now, for my part, the condition of the air in the drains and pipes of my house does not interest me so much as that of its rooms, and my aim is, therefore, to so organize the condition of these drains and pipes as to avoid any possible exit of

the air from them into the house, and to insure an in-draught into the drains if any leak occurs, or if any opening is made into the same by the emptying of a trap, or by some other cause. I begin, as usual, by carrying up a ventilating pipe of suitable proportions alongside my kitchen chimney, the lighter air in which is, as it were, a negative weight always hung on one arm of the air-balance to insure its dropping in that direction if the other end is let go. The next question is: Shall I make other openings from the outside, or from the house into the drain for air circulation? Why should I? If a leak occurs, or if a trap goes dry, such openings would only defeat the object for which I have put in my kitchen-chimney ventilating flue, since they would diminish the suction I aim at.

Second.—If such openings are from the outside, the cold air will be passing through my house in a steady stream, and as the soil-pipes, for practical reasons, are almost always immediately adjacent to the water-pipes, the latter will be liable to freeze in cold weather, a thing which has been actually known to occur in Chicago and elsewhere, owing to this arrangement.

Third.—Do I need such a current to remove germs of disease? No. The flushing action of properly arranged closets is much more effectual than any such circulation, and if anything bad is liable to germinate in the hot, dry, kitchen flue, the puffs of air forced through every time the soil-pipe goes into action will remove them. Furthermore, the air-balance prearranged and assured by the warm column in the sole ventilating flue, makes it impossible for such to pass off, except into the sewers or up the kitchen vent.

I therefore conclude to keep my drains as nearly as I can in the condition of an exhausted receiver, into which the air from the house will pour if any opening is made.

The only cases in which it appears possible to have an escape of air from the house-drains backward into the house through this arrangement, are in the phenomenal event of a close stoppage of the kitchen-chimney ventilating flue occurring at the same time with dry traps, or at a time when the house is not occupied, causing coldness of the kitchen chimney.

The disposal of dead animals, garbage, dust and ashes not suitable for the sewers, and difficult to get rid of by dumping, is a matter which, so far as I know, has been handled with us in the crudest manner, and the same is true generally of Europe.

In 1877, there was built at Leeds one of the so-called "garbage destructors;" and either shortly before or after, the same apparatus was put up at Heckmondwike, Blackburn, Bradford, Warrington and Derby in England, and at Kralingen, near Rotterdam, in Holland. The first destructor at Leeds was erected at Burmantofts, two miles from Leeds Town Hall, in a northeasterly direction, and the second at Armley road, about one mile westerly of the same point. The destroying furnace is the Fryer Patent Destructor.

For a description of this I cannot do better than quote from Mr. Hewson's report of 1884, from which the plans accompanying this, Plates LXXXVIII, LXXXIX and XC, are also taken.

"The destructor consists of ten compartments (at Burmantoft) or cells (five back to back) formed of brick-work, lined with fire-bricks, and tied with iron rods; it occupies a space of thirty-six feet by twenty-four, and twelve feet in height, and is so arranged that there is one inclined road leading from the adjoining road up to a platform, against and higher than the top of the destructor, on to which the refuse is carted, and another inclined road leading from the same adjoining road down to the level of the firing floor, by means of which the mortar, charcoal, old iron, etc., is carted away.

"Each of the cells is capable of destroying six tons of refuse in twenty-four hours, and consists of a sloping furnace with hearth and fire-grate covered in by a reverberatory arch of fire-brick, with one opening at the top for the admission of the refuse, and another opening at the side, near the top, for the gases to escape into the flue, and a furnace frame and doors for the withdrawal of the clinkers. The refuse, which is tipped on to the top cells, is pushed down the incline or throat with a long iron prong, and slides forward on to the sloping hearth, whence, when sufficiently dry, it is helped forward on to the fire-bars, where it burns somewhat fiercely, the fire-brick arch above concentrating the radiant heat upon it. The opening for the entry of refuse is divided from the opening for the exit of gases by a partition-wall with a bridge. These prevent the refuse, which is heaped up immediately below, from finding its way into the flue also. At intervals of about two and a half hours the clinkers are withdrawn through the furnace doors, but the charge of refuse is maintained permanently at the top. The effect of this is that no doors are required, the charge keeping down all smoke. The result of the process is that everything is consumed, or

converted either into clinkers or a fine ash. Every two cells are also provided with an opening (with doors) for the introduction of infected mattresses, diseased meat, etc., on to the fire, where everything is readily consumed without causing a smell in the works.

"The gases from the furnaces on the way to the chimney shaft pass through a multitubular boiler six feet diameter and ten feet in length, and make steam to drive a horizontal engine with twelve-inch cylinder and two-feet stroke, which works two mortar-mills with pans eight feet in diameter. In these the clinkers made in the destructor are mixed with lime and ground into an exceedingly strong mortar, which is readily sold at five shillings per ton. No fuel of any kind is required, the ashes mixed with the refuse being amply sufficient. The old tins and iron which have passed through the furnace are sold for old metal at from five to fifteen shillings per ton; but if collected and sold unburned, they fetch one pound per ton. This is on account of the solder value saved by non-burning.

"The clinker from the furnaces is 25 per cent., by weight, of the refuse consumed."

A carbonizer was formerly used for the special treatment of market refuse, with a view to converting it into a high grade manure; but as it was found that 80 per cent. of the charcoal obtained is simple earth, and therefore of little value as manure, the carbonizer was discontinued, and the whole of the refuse is treated in the ordinary destructor.

The original chimney at Burmantoft was about eighty feet high. As complaints were received of the smells from it, a new one, one hundred and fifty feet high, has been built; and in order to mitigate the discharge of dust over the neighborhood, the horizontal flue has been given the shape shown in the section *C D*, in which the depressions on the sides are to catch the dust, which is removed weekly through doors at the end of each block of cells. Since the rearrangement, no nuisance of any kind is reported.

The Burmantoft destructor consumed during the year ending August 31st, 1884, as follows:

Rubbish	1 538	tons.
Ash-pit rubbish	23 207	"
Beds	45	
Mattresses	96	

Pigs	58
Cows	9
Sheep	9
Quarters bad meat	4

This was the product of about one hundred thousand people. The cost was as follows:

EXPENDITURE.

	£	s.	d.
To cost, £7 282 1s. 1d. Repayment of debt by equal annual instalments of principal and interest during sixty years, at 3½ per cent	291	17	9
" Labor for one year	585	1	0
" Lime	34	18	4
" Depreciation, at 2½ per cent., covering repairs	182	0	6
" Gas, water, rates, etc	126	19	7
	£1 220	17	2

RECEIPTS.

	£	s.	d.
By Mortar	97	18	11
" Charcoal	20	9	6
" Scrap iron	14	15	11
Balance	1 087	12	10
	£1 220	17	2

The Armley destructor sold, for some reason or other, much more mortar, and, therefore, while its total expenses were about the same, the net cost of operating was only £842 4s. 6d.

To compare the cost of running these destructors with that of the removal of refuse otherwise, I will take the case of New York, where the removal of rubbish, etc., after being delivered at the water-front, to deep water, where it is now dumped, costs from $175 000 to $200 000 annually for a population of about one million five hundred thousand, As the cost in Leeds is about $50 per one thousand per annum, the same rate applied to New York would give $75 000 per annum. The circumstances in Leeds are, however, much more favorable than in New

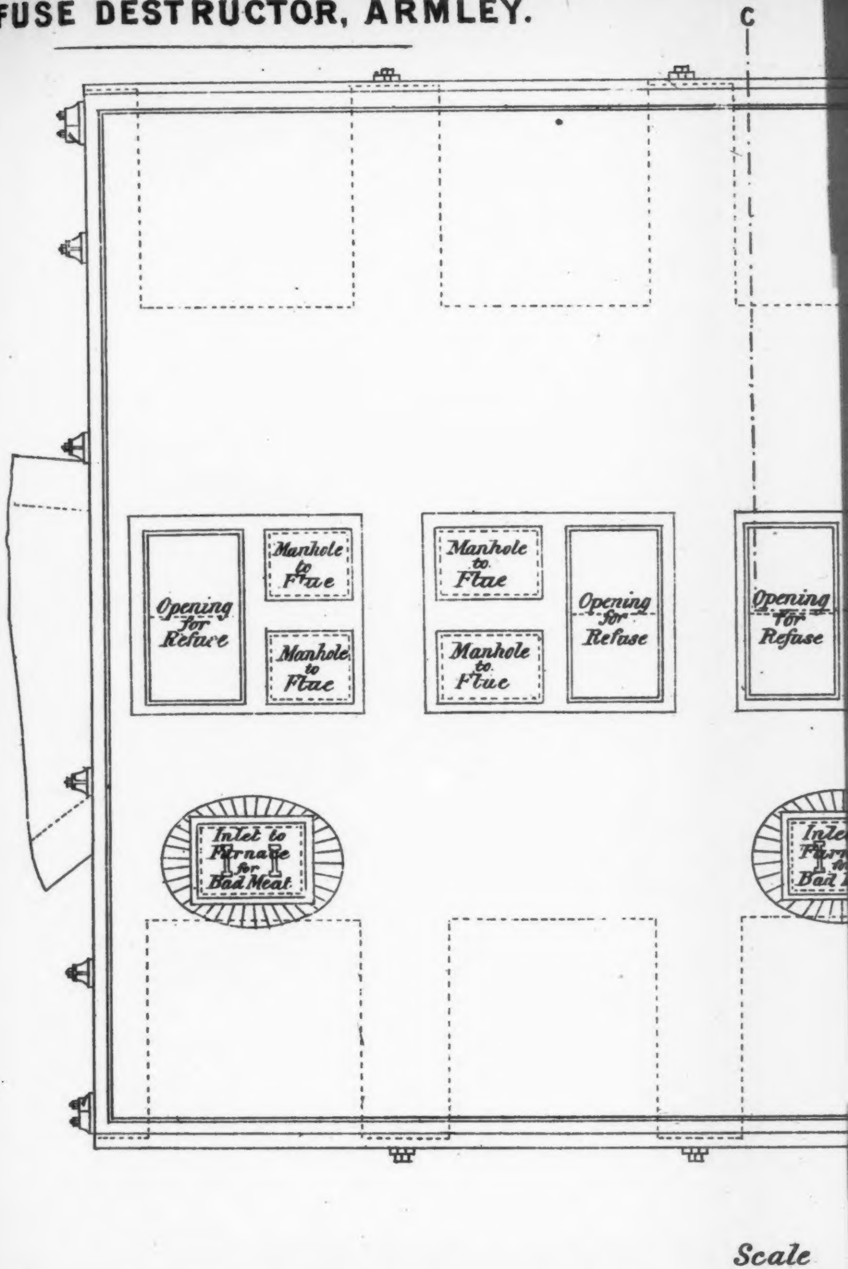
York, since the city has a thinly settled suburb completely surrounding it, and the destructors can be placed on moderately expensive land not available in New York (the Armley destructor at Leeds is, however, somewhat central in position). The rate of interest in Leeds is about three-fourths of what would have to be paid here, and the cost of labor perhaps two-thirds.

Altogether, it seems safe to say that the annual cost per thousand of the population, including all expenses of wear and tear, interest, etc., should not be much, if any, more than double those at Leeds, or $100 00 per one thousand, viz., $150 000 per annum for New York, which leaves a margin for contingencies or profit of from $25 000 to $50 000.

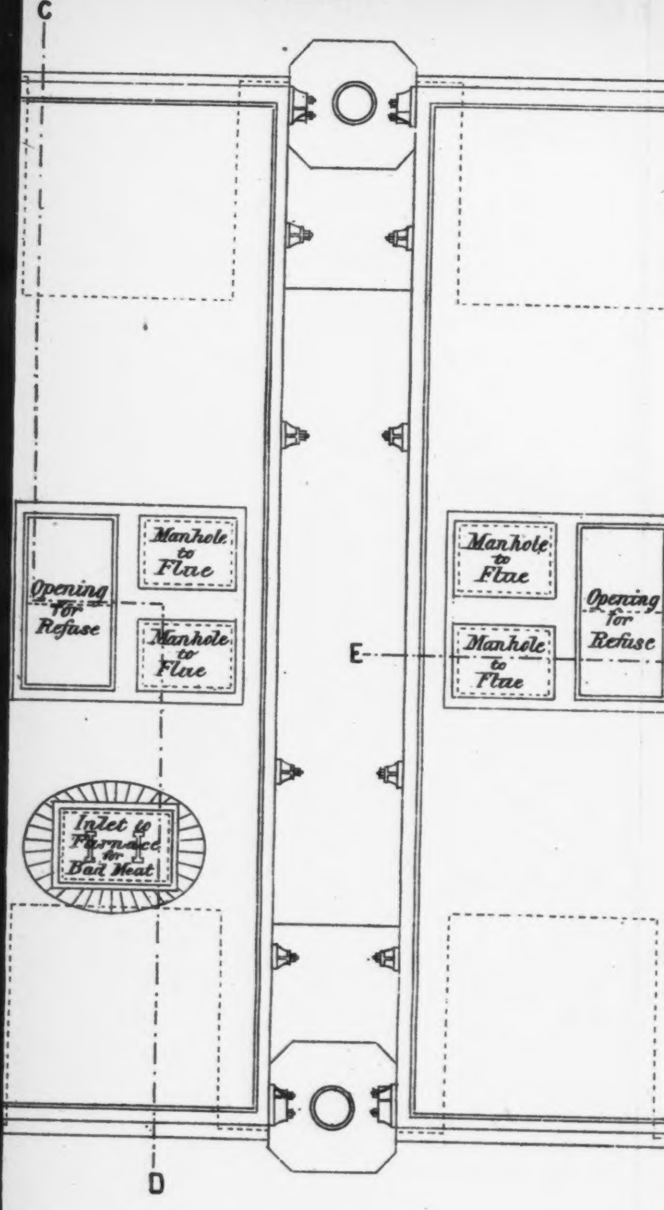
When we have paid this we have absolutely destroyed all injurious elements in the rubbish in the only way which the present state of science indorses as effectual, and we have avoided the nuisance caused by dumping the rubbish into the ocean nearly entirely, the ashes left after burning being a small and innocuous element.

It has been claimed that there is not enough fuel in the rubbish of New York to maintain the necessary fire, but this seems to need proof in view of the English experience. One reason alleged for this is the practice of the poorer population of washing the cinder out of the ashes and reburning it, letting the ashes and the finer cinder go into the sewers. If so, it is time that this practice was stopped by attaching penalties to such washing, and by obliging the owners of tenements to provide dust and ash-spouts, into which the ashes could be sifted instead of into the sewers.

LEEDS CORPORATION
REFUSE DESTRUCTOR, ARMLEY.

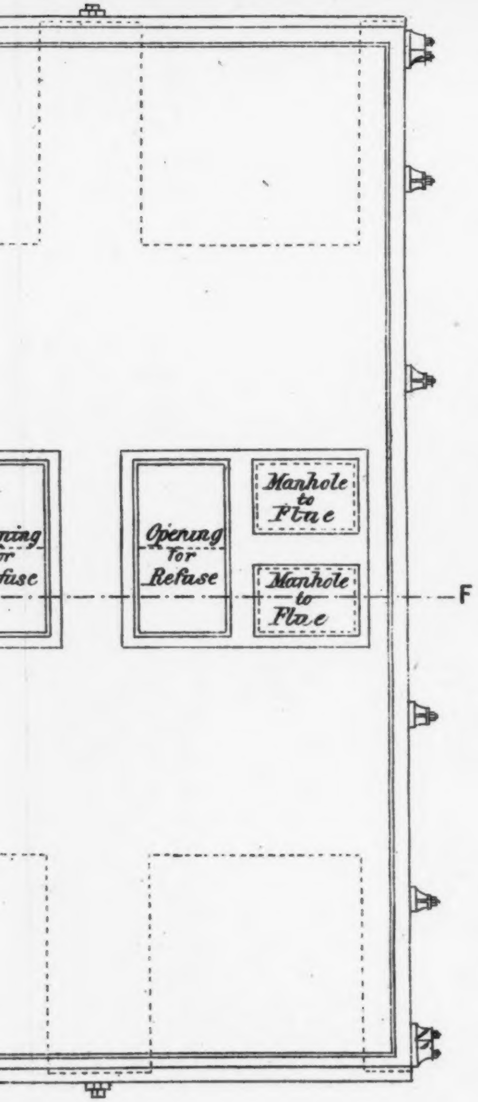


PLAN



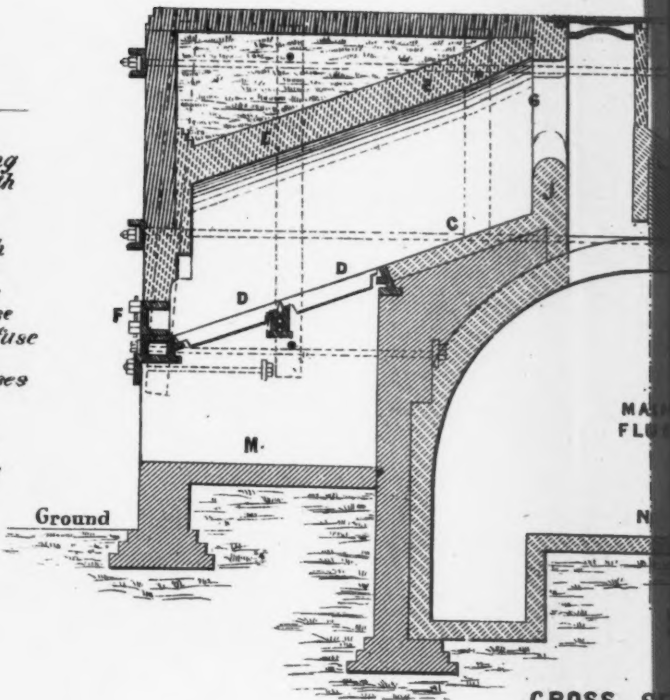
Scale 4 Feet - One Inch

PLATE LXXXVIII
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XV. No 345
WHITE ON EUROPEAN
SEWAGE AND GARBAGE REMOVAL.



REFERENCE

A Refuse Feed Opening
B Incline above hearth
C Drying Hearth
D Fire Bars
E Reverberatory Arch
F Clinkering Doors
G Opening for Gases
H Opening for Refuse
J Bridge to keep Refuse out of the flue
K Wall to divide Gases from Refuse
M Ash Pits
N Flue to Chimney
P Mattress Opening



CROSS S

ON LINE

Scale ¼

PLATE LXXXIX
TRANS. AM. SOC. CIV. ENG'RS.
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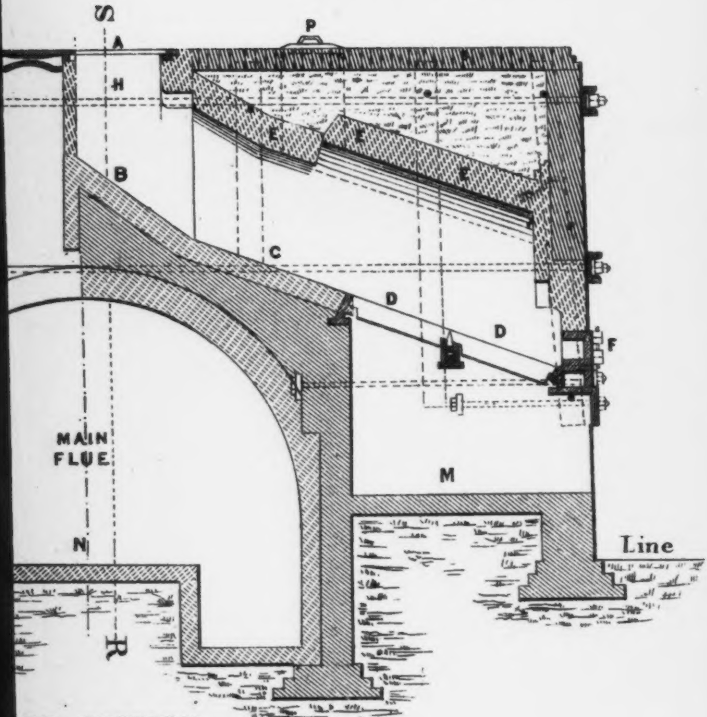
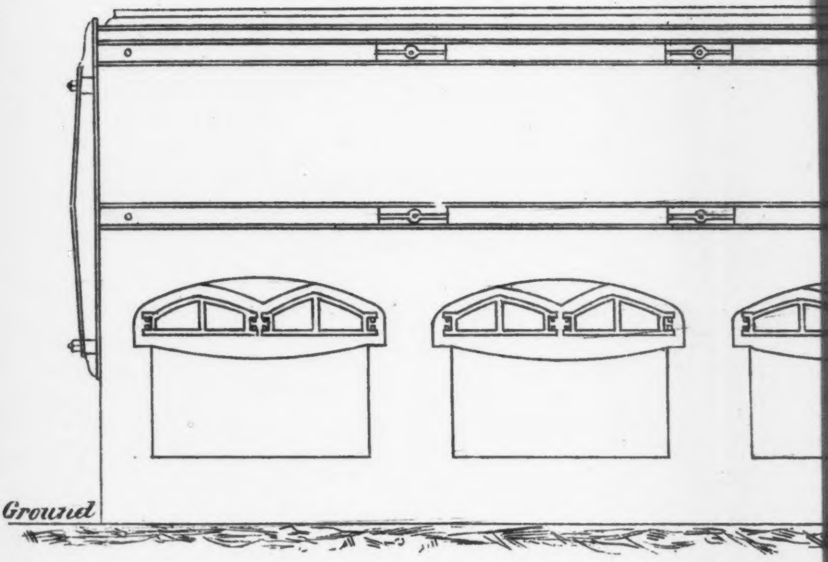
WHITE ON EUROPEAN
SEWAGE AND GARBAGE REMOVAL.



OSS SECTION
LINE C.D.

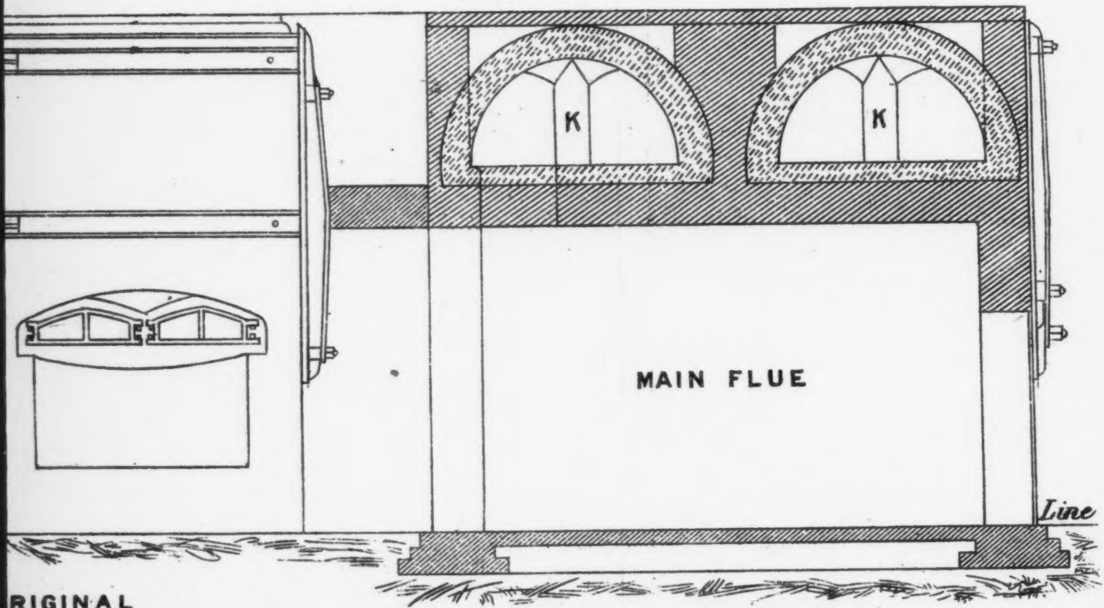
ale 1/4 Inch · 1 Foot



FRONT ELEVATION OF ORIGINA
THREE PAIRS OF CELLS.

Scale 1/4

PLATE XC
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XV. Nº 345
WHITE ON EUROPEAN
SEWAGE AND GARBAGE REMOVAL.



RIGINAL
S.

cale 1/4 Inch = 1 Foot.

SECTION ON LINE E. F.
OF TWO PAIRS OF CELLS
SUBSEQUENTLY ERECTED.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

346.

(Vol. XV.—December, 1886.)

A NOTE ON THE COST OF CONCRETE.

By CAPT. O. E. MICHAELIS, M. Am, Soc. C. E.

READ JANUARY 20TH, 1886.

The Troy Steel and Iron Company's new furnace plant is now erecting upon Breaker Island, situated in the Hudson River not far below Watervliet Arsenal, my present station. The magnitude and scope of this plant may be seen from the following description furnished by Mr. Robert W. Hunt, M. Am. Soc. C. E., General Superintendent of the Company.

THE PLANT.

The entire plant to be located upon Breaker Island will be one of the largest and most complete of its kind known in the history of iron production. The company owns an area of about one hundred acres upon the island. On this land will be constructed three blast furnaces with all requisite appointments. The furnaces themselves will be each of 18 feet diameter of bosh, and 80 feet high. Each furnace will be fitted with four Whitwell fire-brick hot-blast stoves, each 20 feet in diameter and 60 feet in height. The draught stack for the stoves and boilers will be 200 feet high and 12 feet 6 inches in clear diameter. There will be

seven blowing engines with steam cylinders of 42 inches diameter, blowing cylinders of 84 inches diameter and 84 inches stroke. Each engine will discharge at the ordinary working speed 12,000 cubic feet of air per minute, at a pressure of from 10 to 15 pounds. The engines will be built by the Dickson Manufacturing Company, of Scranton, Pa. Steam for the engines will be supplied by sixteen Heine patent safety boilers of 2 400 horse power capacity. These boilers are of recent invention, and are believed to represent the highest effectiveness and economy of service. It is designed that not more than six of the engines shall be in operation simultaneously, the seventh being held in reserve against any contingency that may arise.

Connected with each furnace will be a casting-house, 150 feet long, built of brick, with an iron roof of 50 feet span. The engine-house, which will stand north of the furnaces, will be of brick, 150 feet long by 40 feet wide, and roofed with slate. The boiler-house, adjoining the engine-house, will be 153 feet long by 45 feet wide, of brick with iron roof.

To supply water for the plant, there will be three steam pumps, any two of which will have ample capacity to meet the requirements in this direction, and the same statement will apply to three pumps provided for feeding the boilers. Thus one of each series of pumps will always be held in reserve. The water supply pumps will deliver into an iron water tank standing upon cast-iron columns of thirty feet in height, thus giving a head never less than thirty feet.

There will also be a stock-house, 300 feet long by 100 feet wide, constructed of iron, through which an elevated track will run over pockets into which the material will be dumped from the cars. A substantial dock will be constructed along the river front, 500 feet of which is already under way.

The Foundations.

The work thus far accomplished at Breaker Island, while very great in itself, has been merely preliminary. It consists mainly of building the foundations for the substantial superstructures yet to arise, and for the massive furnaces and their appurtenances necessary to the equipment of the plant. In constructing these foundations, which has been done by the company itself, excavations were made to a bed of gravel overlying slate rock This deposit was found at an average depth of about 15 feet below the surface of the Island. The excavations were

cribbed with timber and filled with concrete to the surface level. The general level of the plant will be 13 feet above the surface of the ground; hence the foundations have been carried to that height. In order to insure the necessary solidity, a superficial wall of stone about 18 inches thick was built up to the required level, and the inclosed space will be filled in with concrete. The hearth level of the furnaces proper will be 6 feet above the general level. The total quantity of concrete used amounts to about 10 000 cubic yards, the largest single mass of which forms the foundations for the Whitwell hot-blast stoves and their draught-stack, the former being 32 feet square and the latter 333 feet long, 27 feet wide, and 33 feet high. Through the center of this mass, and connecting with the draught-stack, is a flue, lined with fire-brick, 310 feet long, 8 feet wide, and 10 feet 6 inches high.

Ground was broken on the Island September 1st, 1885, but it was not until the 20th that the operating force was organized. From that time until December 31st (when the work was discontinued) I had every opportunity of examining the material used as well as to see the methods adopted to insure uniformity and reliabity of result.

The following figures show the amount of work done and material handled within three and one-half months.

There was used for concrete:

Broken stone........................	7 099½	cubic yards.
Gravel	3 487	"
	10 586½	"

There was added to this:

Fine sharp sand......................	1 286	cubic yards.
Hydraulic cement....................	11 832	barrels.

Producing 9 605 cubic yards of concrete.

COST.

7 099½ cubic yards of broken stone	$9 939 00
4 773 " gravel and sand........	1 402 38
11 832 barrels of hydraulic cement	11 832 00
Labor of drawing cement.....................	227 50
" mixing cement.....................	8 153 00
" unloading stone	1 297 03
Four months superintendence...............	1 000 00
	$33 850 91

Cost of concrete in place, $3 52$\frac{43}{100}$ per cubic yard.

The cement used was from New York and Rosendale Cement Company, N. Y.; F. O. Norton Cement Company, N. Y.; J. H. Ramsey's Hydraulic Cement, Howe's Cave, N. Y.; and Eli Rose, Treasurer, Howe's Cave Cement, N. Y.

From the 11 832 barrels of cement there were tests made daily during the progress of the work, both for fineness and tensile strength—for the former with the 10 000-mesh standard sieve, and for the latter with Fairbanks & Co.'s automatic tester. The following is the record. (See tables appended.)

All the cement used was fresh, having been burned not to exceed ten days before, which may account for the high tensile strength shown by all.

The conditions, both as to cost of material and labor, must be considered exceptionally favorable, the broken stone costing $1 41 per cubic yard at the dock; sand and gravel found on the island in close proximity to the work, and costing but 30 cents per cubic yard; and cement at $1 per barrel at the dock.

The concrete, stone walls and other masonry put in place since September 15th, and up to December 31st, amount to 22 365 net tons.

TESTS, NEW YORK AND ROSENDALE CEMENT COMPANY'S CEMENT.

Fineness.	Hours drying.	Tensile strength per square inch.	Fineness.	Hours drying.	Tensile strength per square inch.
		Pounds.			Pounds.
.957	24	90	.955	24	124
.957	24	102	.940	24	129
.945	24	104	.931	24	122
.951	24	117	.967	24	98
.933	24	115	.935	24	106
.943	24	97	.959	24	125
.951	24	97	.949	24	114
.942	24	91	.931	24	95
.937	24	117	.940	24	123
.944	24	118	.945	24	99
.950	24	109	.933	24	113
.939	24	123	.941	24	145
.947	24	117	.945	24	120
.943	24	95	.951	24	90
.943	24	102	.953	24	95
.947	24	104	.935	24	118
.946	24	109	.955	24	113
.944	24	119	.934	24	107
.943	24	112	.934	24	142
.944	24	108	.937	24	116
.951	24	119	.939	24	104
.952	24	121	.936	24	132
.960	24	114	.953	24	116
.961	24	144	.952	24	112
.953	24	138	.950	24	125
.952	24	131	.949	24	104
.952	24	128	.949	24	110
.983	24	125	.951	24	126
.954	24	140	.948	24	114
.941	24	138	.949	24	119
.942	24	122	.946	24	95
.950	24	127	.940	24	124
.952	24	135	.940	24	100
.954	24	125	.941	24	107
.949	24	121	.940	24	96
.950	24	127	.938	24	101
.970	24	132	.942	24	126
.971	24	128	.941	24	98
.970	24	130	.948	24	101
.962	24	139	.953	24	123
.965	24	129	.955	24	121
.971	24	137	.956	24	121
.972	24	124	.946	24	90
.968	24	118	.953	24	143
.957	24	133	.947	24	97
.964	24	120	.937	24	90
.965	24	113	.938	24	98
.945	24	103	.939	36	117
.961	24	114	.910	36	107
.960	24	119	.940	36	115

TESTS, NEW YORK AND ROSENDALE CEMENT COMPANY'S CEMENT.—(*Continued.*)

Fineness.	Hours drying.	Tensile strength per square inch.	Fineness.	Hours drying.	Tensile strength per square inch.
		Pounds.			Pounds.
.948	36	121	.964	48	123
.953	36	112	.914	48	118
.952	36	118	.931	48	116
.952	36	116	.942	48	130
.960	48	178	.920	48	105
.948	48	174	.943	48	137
.948	48	141	.950	48	139
.953	48	159	.960	48	170
.953	48	174	.951	48	150
.943	48	126	.944	48	106
.951	48	115	.950	48	124
.959	48	119			

TESTS, F. O. NORTON'S CEMENT.

Fineness.	Hours drying.	Tensile strength per square inch.	Fineness.	Hours drying.	Tensile strength per square inch.
		Pounds.			Pounds.
.921	24	109	.940	24	118
.900	24	127	.935	24	117
.911	24	119	.935	24	120
.910	24	123	.936	24	119
.913	24	117	.936	24	124
.919	24	103	.928	24	88
.938	24	101	.929	24	102
.939	24	126	.930	24	106
.937	24	142	.928	24	127
.934	24	119	.931	24	98
.937	24	117	.932	24	106
.935	24	111	.930	24	111
.932	24	124	.938	24	101
.932	24	118	.938	24	118
.936	24	123	.950	24	126
.937	24	141	.950	24	115
.939	24	137	.925	24	121
.919	24	126	.926	24	134
.961	24	130	.933	24	120
.943	24	110	.934	24	125
.951	24	137	.933	24	127
.949	24	105	.933	24	143
.921	24	88	.935	24	113
.918	24	121	.934	24	129
.941	24	99	.936	24	134

TESTS, F. O. NORTON'S CEMENT—(*Continued.*)

Fineness.	Hours drying.	Tensile strength per square inch.	Fineness.	Hours drying.	*Tensile strength per square inch.
		Pounds.			Pounds.
.941	24	128	.930	24	97
.935	24	124	.938	24	101
.948	24	136	.924	24	122
.947	24	126	.931	24	96
.948	24	130	.934	24	....
.953	24	126	.934	24	....
.953	24	134	.933	24	....
.947	24	135	.932	24	....
.956	24	134	.935	24	....
.961	24	122	.930	24	107
.949	24	134	.932	24	128
.953	24	134	.922	24	116
.960	24	130	.922	24	112
.957	24	132	.934	48	128
.952	24	129	.934	48	150
.957	24	127	.932	48	146
.955	24	125	.932	48	122
.960	24	124	.932	48	121
.960	24	147	.950	48	163
.951	24	125	.950	48	159
.937	24	131	.952	48	161
.929	24	141	.947	48	168
.947	24	130	.945	48	166
.937	24	104	.926	48	133
.931	24	100	.931	48	130
.919	24	115	.959	48	124
.900	24	116	.920	48	125
.921	24	106	.930	48	127
.915	24	148	.938	48	129
.930	24	113	.945	48	160
.902	24	101	.932	62	135
.941	24	91	.926	62	119
.938	24	108	.927	62	117
.950	24	115	.921	62	133
.951	24	113	.920	62	137
.937	24	123	.932	62	115
.943	24	122	.930	62	127
.930	24	129	.927	62	130
.932	24	126	.931	62	133
.932	24	119	.920	62	119
.922	24	129	.946	192	210
.923	24	127	.951	192	214
.922	24	128	.953	192	216
.931	24	122	.960	192	221
.928	24	92	.941	192	209
.927	24	125	.938	192	208
.931	24	131	.957	192	221
.928	24	146	.961	192	219
.928	24	111	.949	192	217
.931	24	118	.952	192	219

TESTS, J. H. RAMSEY'S HOWE'S CAVE CEMENT.

Fineness.	Hours drying.	Tensile strength per square inch.	Fineness.	Hours drying.	Tensile strength per square inch.
		Pounds.			Pounds.
.932	24	153	.945	24	119
.935	24	127	.943	24	133
.930	24	140	.949	24	116
.934	24	140	.946	24	128
.934	24	157	.946	24	116
.933	24	135	.925	24	109
.935	24	144	.926	24	100
.944	24	125	.925	24	103
.934	24	127	.928	24	112
.952	24	121	.928	24	111
.944	24	124	.949	24	117
.920	24	113	.948	24	117
.900	24	105	.954	24	119
.880	24	109	.950	24	122
.870	24	102	.952	26	121
.880	24	109	.972	26	134
.939	24	112	.970	26	140
.939	24	112	.980	26	130
.944	24	107	.927	26	130
.939	24	120	.928	26	144
.942	24	117	.928	26	140
.966	24	116	.939	26	146
.963	24	118	.889	26	132
.964	24	124	.901	26	136
.964	24	121	.902	26	132
.965	24	155	.906	26	130
.933	24	130	.899	26	130
.939	24	119	.900	26	132
.940	24	124	.981	26	133
.939	24	101	.967	26	110
.940	24	116	.968	26	127
.929	24	108	.971	26	127
.930	24	113	.971	26	140
.939	24	104	.963	26	106
.931	24	124	.958	26	117
.931	24	113	.965	26	116
.959	24	124	.961	26	117
.962	24	113	.960	26	116
.963	24	120	.971	20	102
.961	24	117	.969	24	147
.960	24	113	.987	24	177
.923	24	115	.949	24	126
.923	24	107	.961	24	165
.934	24	113	.961	24	159
.923	24	104	.968	24	131
.928	24	116	.970	24	152
.924	24	101	.968	24	156
.914	24	107	.975	24	139
.913	24	112	.987	24	119
.913	24	102	.990	24	168
.914	24	143	.997	24	173

TESTS, J. H. RAMSEY'S HOWE'S CAVE CEMENT—(*Continued*).

Fineness.	Hours drying.	Tensile strength per square inch,	Fineness.	Hours drying.	Tensile strength per square inch.
		Pounds.			Pounds.
.996	24	116	.946	24	141
.959	24	124	.919	24	135
.980	24	184	.896	24	131
.990	24	162	.901	24	146
.945	24	155	.902	24	146
.985	24	150	.889	24	121
.982	24	145	.896	24	132
.973	24	127	.965	24	127
.979	24	170	.950	24	99
.987	24	145	.956	24	125
.973	24	138	.952	24	124
.986	24	117	.954	24	129
.971	24	170	.916	24	131
.973	24	139	.914	24	132
.952	24	132	.920	24	132
.960	24	146	.916	24	144
.952	24	148	.919	24	146
.985	24	145	.955	24	132
.990	24	145	.950	24	133
.987	24	164	.957	24	143
.990	24	141	.955	24	146
.982	24	143	.957	24	149
.978	24	138	.919	24	143
.979	24	182	.919	24	124
.992	24	132	.934	24	137
.994	24	168	.965	28	160
.971	24	110	.963	28	177
.998	24	141	.970	28	142
.979	24	139	.967	28	158
.965	24	137	.983	28	131
.980	24	126	.963	28	127
.973	24	138	.971	28	121
.977	24	103	.981	40	139
.981	24	138	.965	40	121
.982	24	146	.938	40	145
.969	24	155	.941	40	120
.967	24	143	.955	40	117
.980	24	132	.927	40	123
.967	24	120	.951	40	137
.935	24	181	.953	48	149
.979	24	159	.948	48	136
.977	24	146	.957	48	150
.974	24	130	.949	48	165
.974	24	180	.936	48	179
.973	24	192	.978	48	152
.974	24	179	.948	48	157
.974	24	175	.953	48	141
.972	24	186	.907	48	142
.942	24	141	.906	48	143
.948	24	150	.906	48	135
.954	24	140	.903	48	152
.946	24	147	.906	48	129

TESTS, J. H. RAMSEY'S HOWE'S CAVE CEMENT—(*Continued*).

Fineness.	Hours drying.	Tensile strength per square inch.	Fineness.	Hours drying.	Tensile strength per square inch.
		Pounds.			Pounds.
.964	48	190	.900	48	134
.970	48	197	.961	62	200
.966	48	161	.957	62	200
.985	48	154	.956	62	157
.962	48	149	.957	62	190
.977	48	176	.951	62	199
.987	48	171	.955	62	121
.944	48	147	.947	62	134
.942	48	132	.959	62	170
.938	48	142	.987	62	126
.946	48	150	.991	62	148
.946	48	147	.974	62	150
.965	48	112	.969	62	167
.967	48	102	.966	62	150
.970	48	102	.960	62	162
.963	48	104	.944	62	142
.966	48	111	.947	62	145
.898	48	142	.948	62	159
.897	48	145	.946	62	145
.903	48	122	.947	62	142
.902	48	131			

TESTS, ELI ROSE, TREASURER, HOWE'S CAVE CEMENT.

Fineness.	Hours drying.	Tensile strength per square inch.	Fineness.	Hours drying.	Tensile strength per square inch.
		Pounds.			Pounds.
.917	24	104	.852	24	135
.920	24	104	.825	24	137
.922	24	102	.830	24	120
.921	24	106	.835	24	147
.926	24	101	.819	24	150
.978	24	107	.829	24	150
.974	24	102	.824	24	151
.978	24	100	.822	24	153
.976	24	112	.792	24	160
.975	24	101	.794	24	154
.941	24	111	.804	24	150
.918	24	149	.806	24	145
.939	24	137	.796	24	146
.843	24	134	.880	24	131
.847	24	123	.882	24	161

TESTS, ELI ROSE, TREASURER, HOWE'S CAVE CEMENT—(*Continued*).

Fineness.	Hours drying.	Tensile strength per square inch.	Fineness.	Hours drying.	Tensile strength per square inch.
		Pounds.			Pounds.
.883	24	123	.853	24	93
.882	24	132	.843	24	98
.881	24	169	.855	24	96
.873	24	144	.890	24	98
.900	24	120	.879	24	99
.900	24	112	.889	24	138
.906	24	118	.888	24	138
.900	24	126	.888	24	129
.895	24	124	.905	24	144
.862	24	125	.892	24	133
.868	24	147	.893	24	103
.863	24	168	.906	24	118
.862	24	153	.918	24	137
.866	24	146	.911	24	139
.939	24	149	.919	24	140
.901	24	139	.911	24	138
.943	24	108	.876	24	107
.941	24	151	.871	24	122
.943	24	158	.877	24	124
.922	24	132	.853	24	131
.894	24	137	.870	24	124
.921	24	134	.960	24	120
.905	24	140	.957	24	115
.910	24	124	.954	24	124
.921	24	149	.957	24	120
.926	24	135	.941	24	114
.920	24	155	.916	24	128
.921	24	150	.872	24	136
.918	24	160	.875	24	134
.937	24	159	.806	24	145
.934	24	114	.900	24	136
.941	24	119	.958	24	114
.940	24	105	.963	24	104
.935	24	107	.960	24	119
.891	24	116	.962	24	117
.896	24	147	.961	24	117
.894	24	142	.914	48	125
.892	24	176	.915	48	123
.844	24	182	.900	48	123
.840	24	146	.895	48	121
.842	24	119	.945	48	119
.838	24	114	.938	48	123
.820	24	112	.933	48	137
.735	24	115	.932	48	134
.739	24	118	.940	48	119
.763	24	112	.929	48	123
.746	24	102	.900	48	163
.755	24	108	.909	48	171
.853	24	120	.907	48	157
.863	24	109	.900	48	157

TESTS, ELI ROSE, TREASURER, HOWE'S CAVE CEMENT—(*Continued.*)

Fineness.	Hours drying.	Tensile strength per square inch.	Fineness.	Hours drying.	Tensile strength per square inch.
		Pounds.			Pounds.
.904	48	118	.855	69	154
.882	48	151	.898	92	174
.895	48	151	.900	116	179
.883	48	149	.901	140	163
.890	48	125	.901	164	174
.905	68	133	.900	212	209
.852	69	174	.904	236	207
.882	69	163	.899	260	251
.878	69	150	.900	284	270
.885	69	151	.901	308	340

At the meeting of the Society, May 19th, 1886, questions were asked by Members as to the condition of this large monolithic mass of concrete six months after its construction; as to the high tensile strength of the cement in twenty-four hours; as to the cost of the concrete in days' work; and as to the low cost of this construction. The author of the paper replies in the following note:

I will try to answer the questions *seriatim.* The past winter was very severe; upon the breaking up of the ice above we had higher water than ever before, except in the famous 1857 freshet. The concrete mass, subjected to the action of ice and water, stood intact. Here and there I detected some slight faults, which were excised, and probably in measure did not amount to more than a barrel. No cracks or settling have been observed, and the work of building is now going on rapidly.

The parties who furnished the cement, all named in the paper, would doubtless gladly supply any quantity ordered. The question as to cost in days' work is met by the facts given, 11 832 barrels of cement, and $1 per day for all labor, except superintendence. I again must invite attention to the favorable conditions under which this work was done. The main plant was shut down and out of blast; the employees gladly accepted this job at $1 per diem. They felt they were working for their future good, and, animated by a genuine *esprit de corps*, they wrought with a will, and accomplished much.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

347.
(Vol. XV.—December, 1886.)

THE WATER-WORKS OF SOUTHINGTON, CONNECTICUT.

BY THEODORE H. MCKENZIE, M. Am. Soc. C. E.

READ FEBRUARY 3D, 1886.

The town of Southington, in Hartford County, Connecticut, is the seat of several large manufacturing establishments. It is on the Quinnipiac River, in a valley surrounded by hills rising 600 feet above the level of the stream.

Works for supplying water for domestic use and fire protection were constructed by a private corporation, "The Southington Water Company," in 1883-84, after the plans and under the direction of the writer. The water is procured from Humiston's Brook, a mountain stream having a drainage area of two and one-half square miles, mostly uncultivated, rocky land, with very irregular surface. The rock is granite. The water is impounded by an earth dam about four miles from Southington Centre and 530 feet above its level. Another distributing reservoir is built three-fourths of a mile nearer the town and 242 feet above it, from which a cast iron-pipe is laid to the town.

The gaugings of the stream, taken at the distributing reservoir during the year 1883, showed an average daily flow of 4 300 000 gallons. The gathering ground is particularly favorable to the preservation of

the purity of the water on account of the freedom from swamps and the sparse population, there being but three houses within the entire area.

STORAGE RESERVOIR.

The storage reservoir covers an area of 23 acres, with 25 feet in depth of water at the dam, and has a capacity of 60 000 000 gallons. The valley in which this reservoir lies is of such form that nearly the entire area is covered with deep water, the sides being quite abrupt. The bed is of rock and gravelly soil; the ground was thoroughly cleared of all wood and vegetable growth, and burned over.

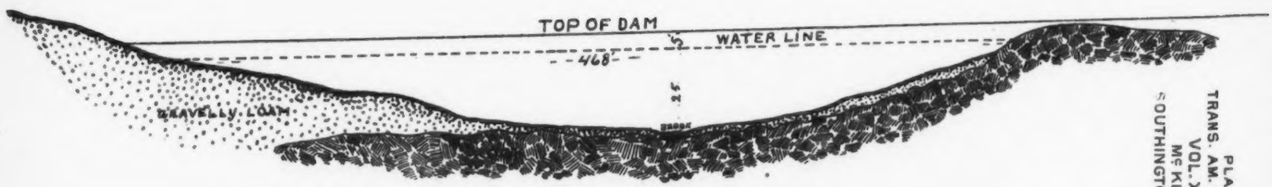
STORAGE RESERVOIR DAM.

The dam is mostly of earth. It is 520 feet long, 16 feet wide on the top, and 30 feet high, with stone masonry and puddle heart wall and dry stone slope wall. The water slope is two to one, and the outer slope one and one-half to one. (Plates XCI and XCII.)

The surface soil was entirely removed from the site of the dam for a depth of two feet or more, and wherever the bed rock lay within four feet of the surface the earth overlying it was entirely removed. The bed rock was reached for about two-thirds of the length of the dam. Where it was not reached a center trench 10 feet wide was excavated for a depth of about four feet below the average bed of the dam, and a cemented stone masonry wall 4 feet thick was built in the center of the trench and carried to an average height of 5 feet for nearly the entire length of the dam. The surface of the rock under the wall was washed clean in order that the cement might properly unite with the rock.

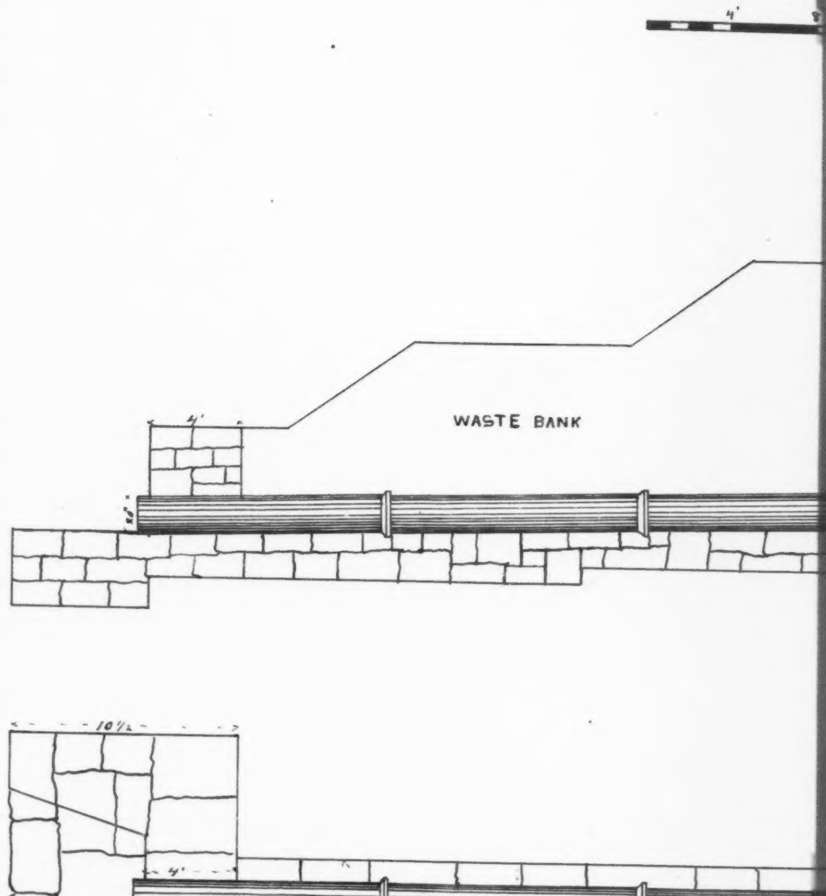
On each side of the masonry wall, and for the entire height and length of the dam, a puddle wall was built, 10 feet in thickness at the bottom and 6 feet at the top. It was carried up simultaneously with the rest of the dam, and was composed of one part clean, sharp sand and two parts loam, which was thoroughly mixed and wet and then worked with spades in 6-inch layers. The earth for the remainder of the dam was carefully selected loam free from turf, roots or stones, and was put on in horizontal layers of not more than six inches in depth, each layer being thoroughly wet and rolled compact with a 3-ton grooved iron roller. The excavated material was put in a waste bank at the foot of the lower slope, and will form a part of the dam in the event of its being raised.

PLATE XCI.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XV. Nº 347
Mc KENZIE ON
SOUTHINGTON WATER WORKS.

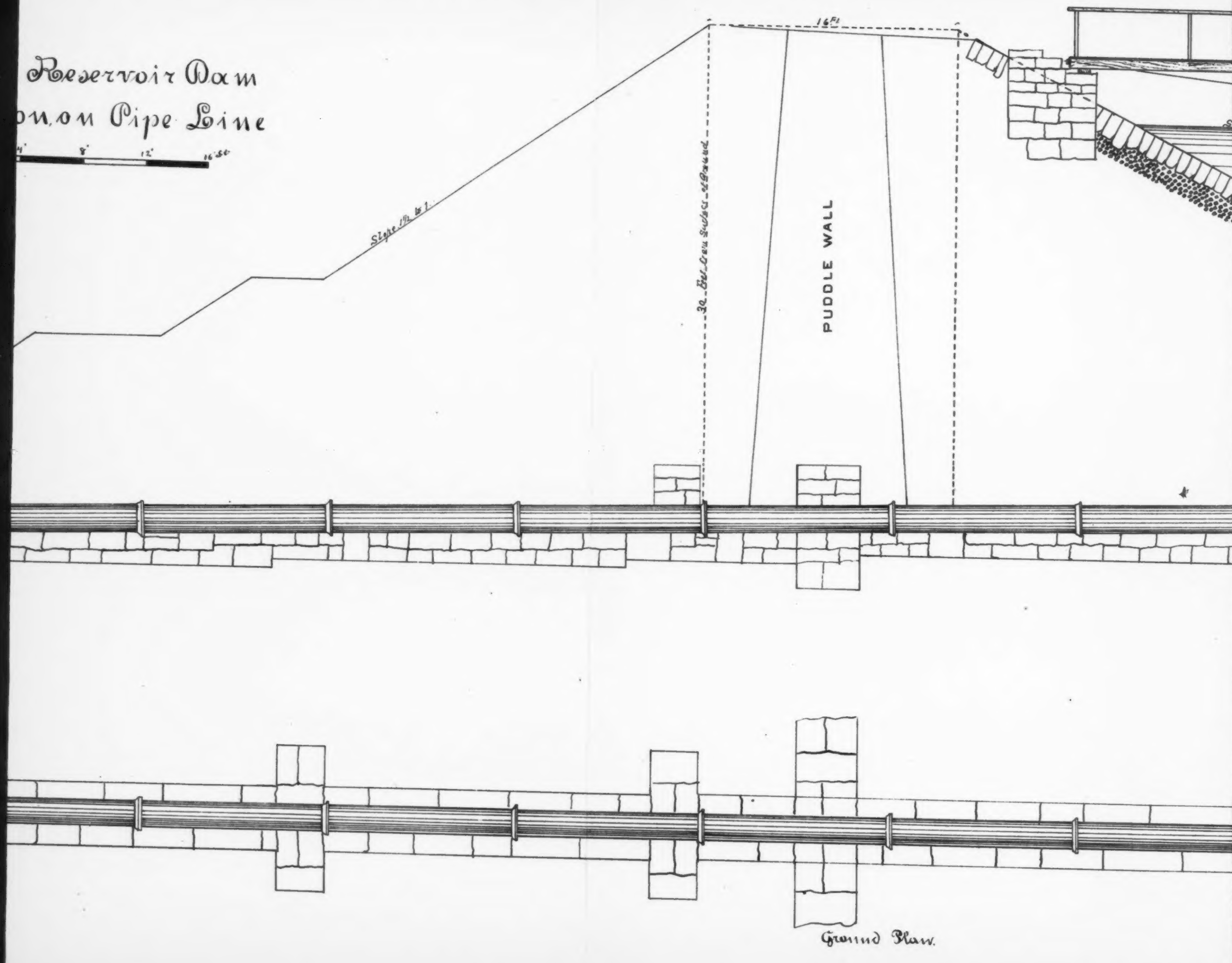


PROFILE ON LINE OF STORAGE RESERVOIR DAM

Storage Res
Crossection, o



Reservoir Dam
on, on Pipe Line



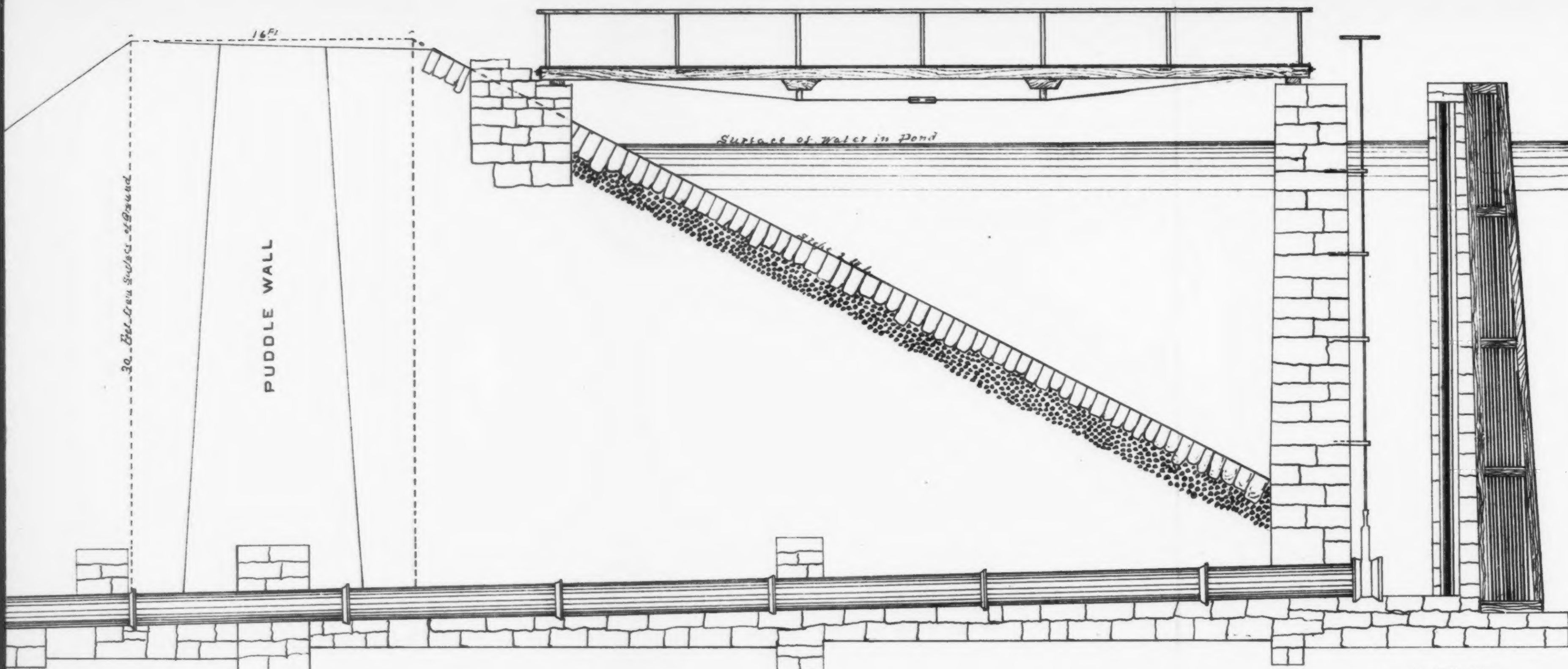
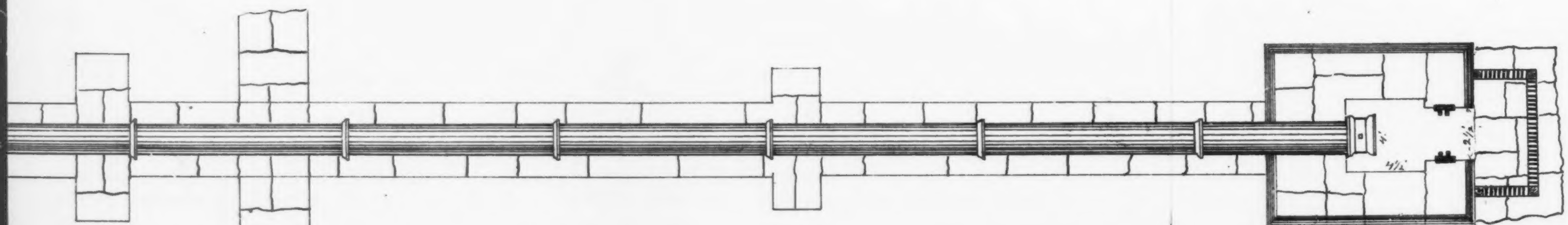


PLATE XCII.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XV. No 347
McKENZIE ON
SOUTHINGTON WATER WORKS.



Ground Plan.

The water slope of the dam was covered 18 inches in depth with small broken stone, over which was laid a paving of large stone 15 inches in depth.

The top of the dam is 5 feet above the bed of the overflow.

A 20-inch cast-iron pipe is laid through the dam on a heavy masonry wall for its entire length, with short cut-off walls every 24 feet to break the continuity of the surface and prevent the water following the pipe through the dam. The masonry under the pipe, and also the wing walls at the outlet are founded on the bed rock. The pipe is 144 feet in length, and terminates at the upper end in a 20-inch stop-cock set in a square chamber with side walls of masonry extending the full height of the dam. On the side toward the reservoir an opening is left two feet wide and faced with grooved iron castings in which gates of 3-inch white oak plank (made in sections) are fitted to slide, so that the water can be entirely shut out or drawn from any depth desired.

An overflow or wasteway, 28 feet in width at the bottom, was excavated through the solid rock at the east end of the dam, through which the water is conducted back to the channel of the brook below the dam.

The materials moved in the construction of the dam were as follows:

Excavation on the site of the dam and overflow, and clearing to obtain suitable filling material for the dam.....	4 600	cubic yards.
Loose and solid rock excavated........	237	"
Earth filling in the dam...............	19 000	"
Masonry in walls and foundations......	375	"
Masonry in well chambers.............	89	"
Slope paving.........................	1 300	"

The dam was built by contract, the company keeping an inspector on the work,

The water from the storage reservoir follows the original channel of the brook for a distance of three-fourths of a mile and is aerated by flowing over the rocky and precipitous bed, and much better fitted for use than if taken directly into the pipes from the storage reservoir.

Distributing Reservoir.

The distributing reservoir is formed by erecting a masonry dam 20 feet in height from the bed of the stream to the overflow, and, when full, covers an area of one and one half acres and contains three million gallons. The bed of the reservoir was cleared of all wood and vegetable growth and burned over, and the woods surrounding the reservoir

cleared off 30 feet or more outside the flow line. The dam is 170 feet long on the top, 14 feet thick at the base, and 5 feet thick at the overflow, 20 feet above the base. The remainder of the dam is carried 3 feet higher, and is 4 feet thick at the top. (Plates XCIII and XCIV.)

The bed of the stream was a quicksand, which lay very firmly in its natural bed. The foundation was prepared by excavating two trenches parallel with the face of the dam to a depth of about three feet. Sills were laid at the bottom and top of the excavation and sheet piling driven and spiked to the sills; the trenches were then filled with concrete, and a layer of concrete 1 foot thick by 15 feet wide covers the entire surface under the dam. The dam is built of granite rubble masonry. The stone was quarried within 1 000 feet of the dam. Every stone was cleaned and wet before laying, and was laid in a full bed of cement-mortar; all interstices were filled with mortar and stone driven into it.

Well-chamber and Gate-house.

The dam forms the lower side of the well chamber, which is 6 by 8 feet in the clear inside, and is built of the same class of masonry as the dam. The walls are three and a half feet thick at the base and two feet thick at the top, lined with a brick wall eight inches thick. A 4-inch space between the brick and stone is filled with pure cement-mortar. There are two inlets from the reservoir to the well. The upper one is operated by a sliding plank gate and draws water from the surface and to a depth of five feet. The lower inlet is through a pipe and culvert extending to the foot of the slope. This inlet draws the water to a depth of twelve feet below the surface of the water, thus giving the advantage of drawing from any depth as the season of the year or the varying condition of the stream may indicate.

A 12-inch waste pipe extends through the dam and well-chamber and draws water to a depth of sixteen feet below the surface. By closing all the inlets to the well and opening a 6-inch waste gate at the bottom, it can be entirely emptied in five minutes and the well cleaned without interfering with the supply, as the water in the main pipe will furnish a supply for the short time required for any ordinary work within the well.

The water, before entering the well, passes through an iron rack or screen covering the inlets to the well, the rods of which are 2 x ½ inch iron and set one inch apart. Within the well the water passes through

two sets of copper wire screens of half and quarter-inch meshes. The screens are set in a cross wall in the center of the well with an opening three feet wide for the whole depth. On the jambs of the opening is anchored a cast-iron frame with grooves lined with Babbitt metal in which the screens slide, and are easily raised by a rope and pulley overhead for the purpose of cleaning. The inlet and outlet pipes are regulated by means of stop-cocks with iron rods extending three feet above the floor of the gate-house, and are operated by brake wheels eighteen inches in diameter. A brick gate-house 11 by 13 feet covers the well. The foundations of the dam are protected from wash under the overflow by a paving of large stone, 3 feet in depth, 50 feet in length and 20 feet wide from the front of the dam. On the top of this is laid a timber and plank apron 10 feet wide for the length of the overflow 40 feet.

The filling back of the dam is of selected materials, free from turf, roots or stones; it was put on in level courses and puddled against the back of the dam; the slope is two to one on the water side.

The materials moved in the construction of the dam were as follows:

Earth exacavtion	750	cubic yards.
Loose and solid rock excavation	76	"
Earth filling back of the dam	1 419	"
Masonry laid in cement	1 021	"
Bank wall and paving	110	"
Concrete in foundations	86	"
Bricks in well and gate-house	17 000	
Timber in apron and sheet filling	4 500	feet.

The work was done by contract. Work was begun on both dams July 1st, 1883, and completed October 1st, 1884; work was discontinued during freezing weather.

Main Supply Pipe.

The main supply pipe through the dam is 12 inches in diameter, and from the dam to the Plantsville Railroad crossing it is 10 inches in diameter; the general depth of the bottom of the pipe is five and one-half feet. The pipe is all accurately laid to a grade with very few horizontal bends, and no curves with a less radius than thirty feet; there are no vertical bends, except at the four summits in the grade, where air-valves are placed to relieve the pipes of any accumulation of air. Blow-offs are placed at each depression in the grade. (Plate XCV.)

The pipe is laid over the river on permanent iron bridges, as in the event of any accident or leakage they are more easily accessible for repairs. The pipes over the bridges are covered with asbestos and felt covered with pitch to protect it from the weather.

The thickness and weights of pipes are adjusted to the pressure due to each one hundred feet of head, according to the following schedule.

SCHEDULE OF CAST-IRON WATER-PIPE TO BE FURNISHED.

Class.	Diameter in inches.	Thickness in decimals of an inch.	Number of pieces.	Stand'd weight in pounds of each piece.	Gross weight in tons.
A	12	.520	16	828	6
A	10	0.489	160	659	47
B	10	0.549	657	742	217
C	10	0.579	223	786	78
C	8	0.522	703	572	180
C	6	0.466	1 275	386	220
C	4	0.409	10 000	232	103
C	....	....	Special castings	....	10
			Total tons	....	861

All pipes were coated by the ordinary process of immersion in a bath of coal-tar pitch properly heated, and were tested to a pressure of 300 pounds per square inch; the hubs of 10 and 8-inch pipe were 4 inches deep, and for 6 and 4-inch pipe $3\frac{1}{2}$ inches deep, with not less than $\frac{31}{100}$-inch joint room. A groove or recess was cast on the inner surface of the hub, and a bead on the spigot end.

DISTRIBUTION.

From the end of the 10-inch main at Plantsville Railroad crossing, the water is conveyed to Southington Centre by two lines of 8 and 6-inch pipe, and by branch lines of 6 and 4-inch pipe, quite generally distributed about the thickly settled portions of the town, as shown by the accompanying map. (Plate XCVI.)

In some streets and lanes wrought iron-pipe was used to supply tenements, which were protected from fire by hydrants on other streets. Branches were set at the intersection of nearly all the streets for future extension, and gates located at convenient points to shut off and control the water, and avoid the necessity of cutting off a large territory in case of a break.

Blow-offs are located at the crossings of all streams and at other low points in the grade.

There are some extensions of 4-inch pipe yet to be made to complete the original plan and give a good circulation.

The distribution pipes are all laid to a grade, and all summits in the grades arranged so that a house-service pipe acts as an air vent.

Profiles were made and grades adopted on all streets where pipe was laid.

A record was preserved of the location of every gate, both on the mains and house service, so that they can be readily found when the ground is covered with snow.

The entire amount of pipe laid by the company, not including house-service pipe, is $11\frac{55}{100}$ miles.

Hydrants are set at all street intersections, and on long streets usually not more than 500 feet apart; the total number set to date is 69.

The pressure over most of the town is from 90 to 100 pounds to the square inch.

The capacity of the works is such that they will supply five or six fire streams on any of the manufacturing property of the town without seriously affecting the pressure.

The quality and purity of the water is all that could be desired.

The total cost of the works to date is $88 753. The cost is divided about as follows:

Storage reservoir, land, dam, pipes, etc...........	$17 500
Distributing reservoir, land, dam, pipes, etc......	8 500
Mains and distribution pipes, hydrants, gates, etc.	52 753
Engineering and superintendence...............	5 500
Paid mill-owners for water rights...............	4 500
	$88 753

In the designing and management of the work, the writer was aided by the advice of Mr. J. J. R. Croes, M. Am. Soc. C. E., as consulting engineer, and in the field work and supervision of construction by John M. McKenzie, C.E.

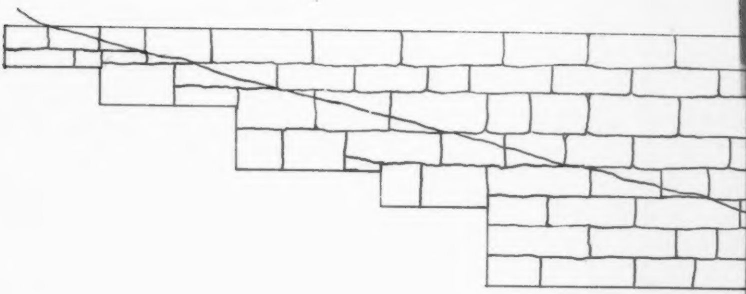
The fact that no leaks have appeared and no failure of any kind occurred in the dams, pipes or fixtures, would seem to indicate that the works were well constructed, and at a very moderate cost as compared with other similar works.

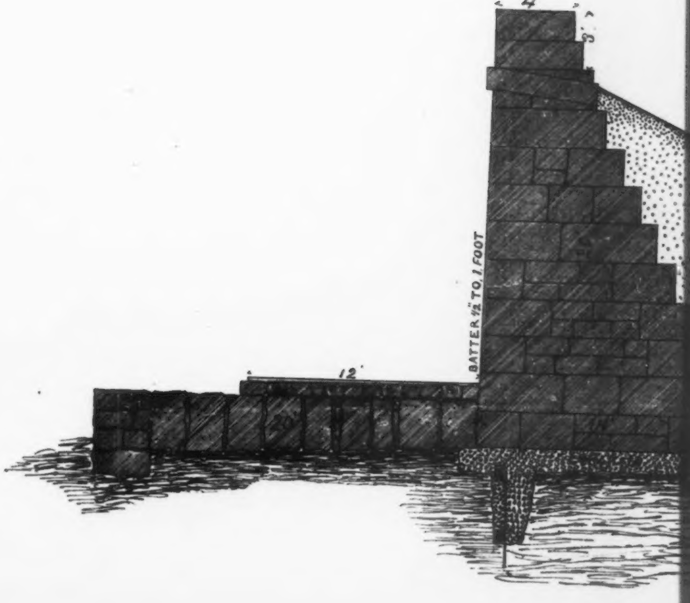
The water of deep reservoirs (particularly new ones), if drawn from the bottom, is often foul and unfit for use, and for that reason the wells at both reservoirs are so arranged as to draw water from the most desirable levels.

The stop-cocks at both dams are located on the upper side of the dams, relieving the pipes under the dams from pressure which would produce the most disastrous results in the event of the smallest leakage under an earth dam.

The pipes and dams are built with a large factor of safety. The lead joints were of more than ordinary depth and thickness; every joint was shoved home to the shoulder of the hub and the earth was thoroughly rammed under and around the pipe, and all were laid to such a depth as to preclude the possibility of freezing.

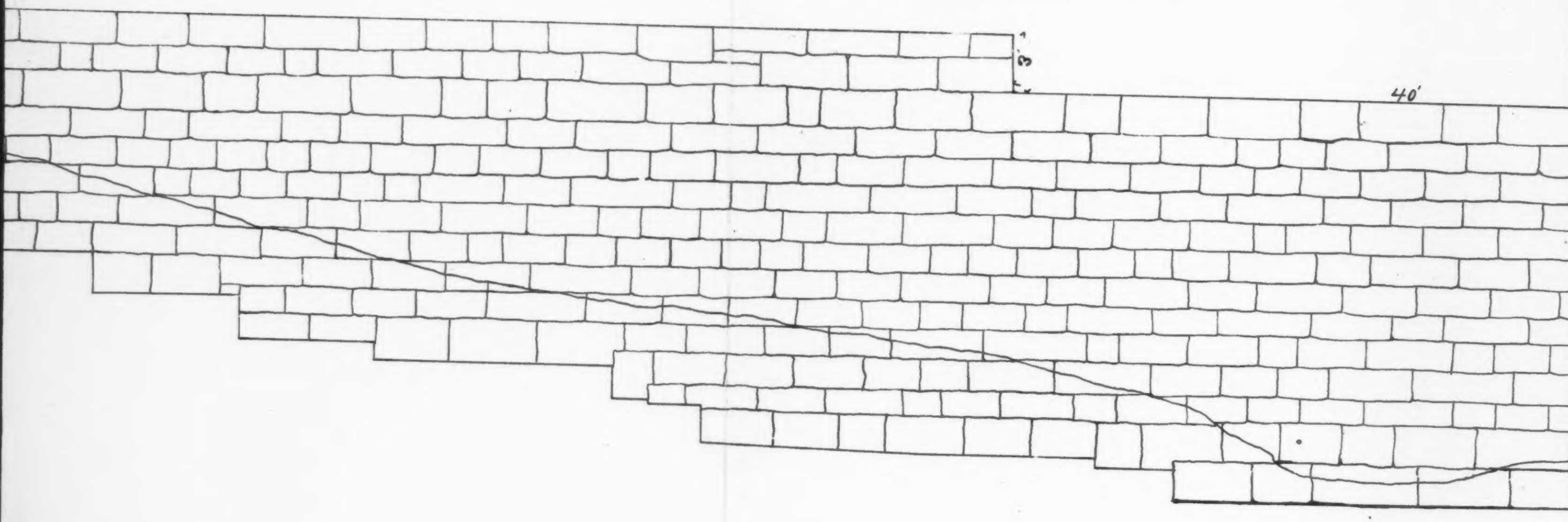
In the construction of many of the water-works for small towns in the New England States, but little attention has been given to the grades of pipes, and in laying pipe the undulations of the ground are followed without relieving the accumulations of air at the summits, and consequently the flow of the water in the pipes is impeded; but the works above described have been constructed with the idea in view that money judiciously expended in engineering, planning and superintending was a good investment, and the results confirm that theory.

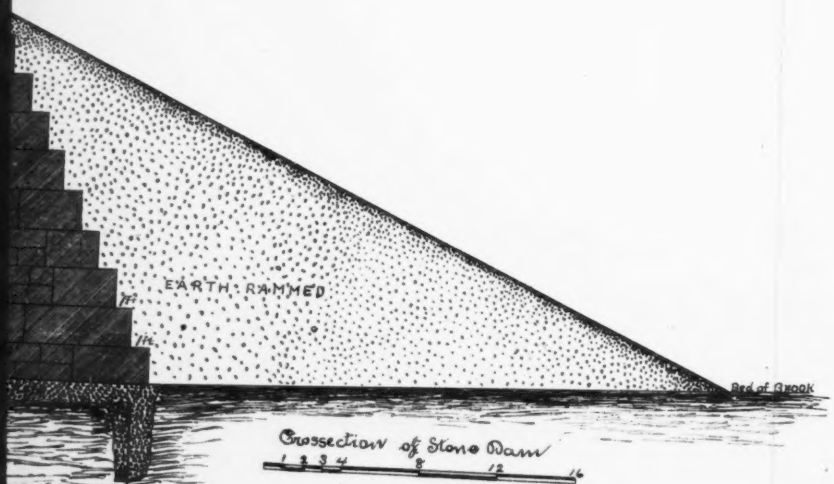



4'
12'
BATTER ½" TO 1 FOOT

Profile at Stone Dam.

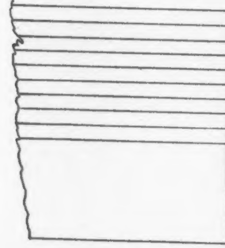
Scale: 4' 8' 12' 16 ft





Crossection of Stone Dam

1 2 3 4 8 12 16



Profile at Stone Dam.

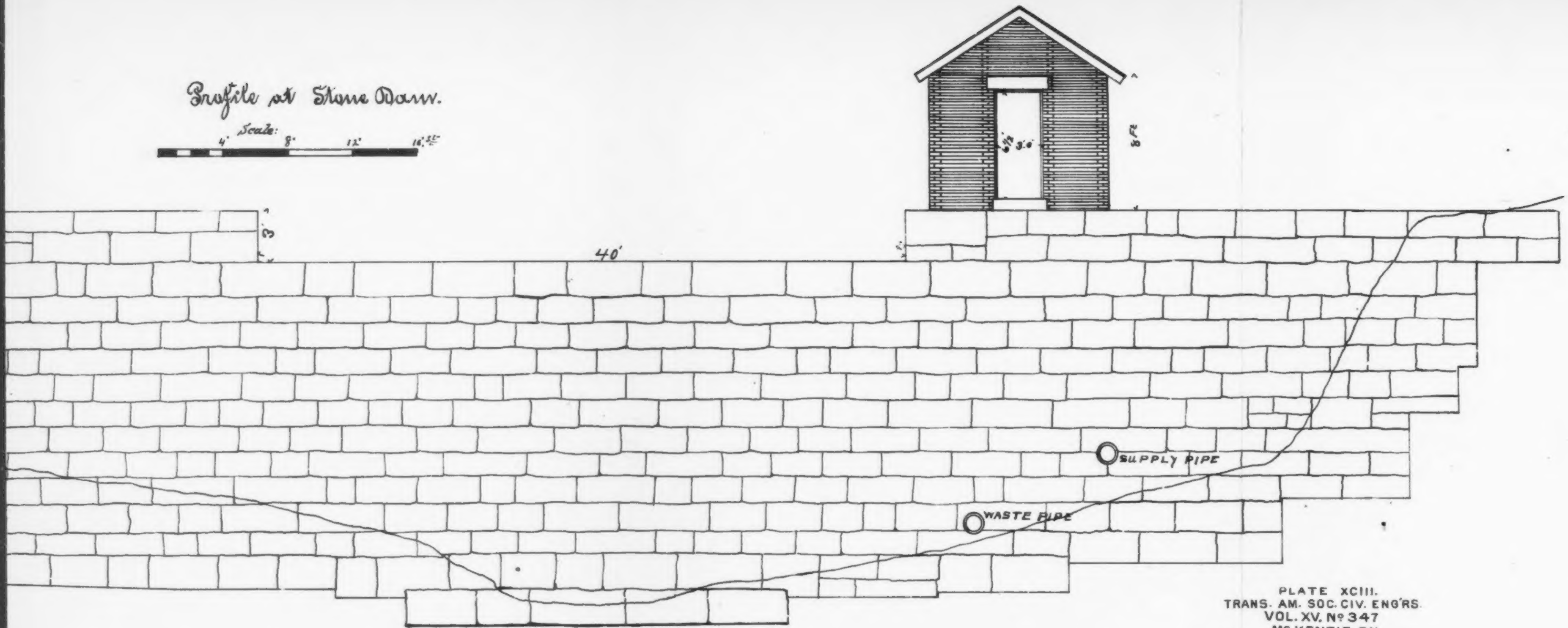


PLATE XCIII.
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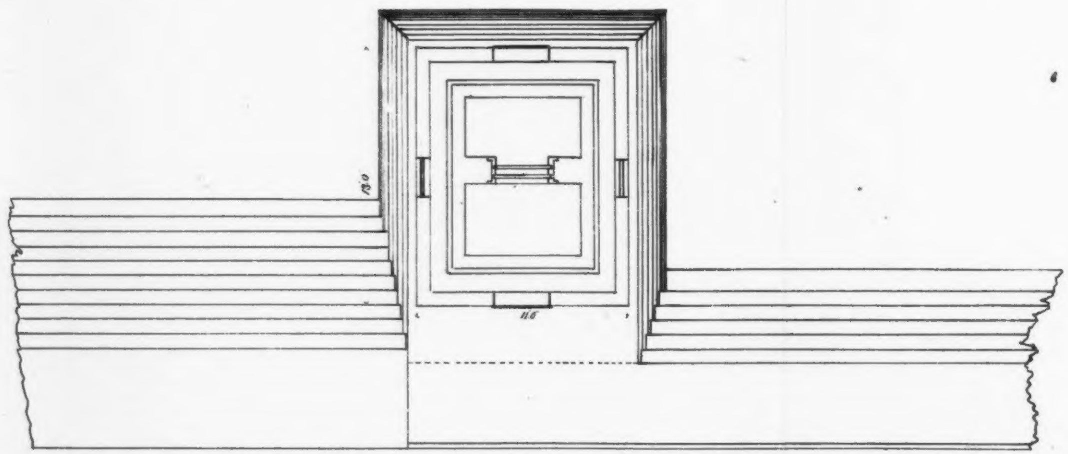
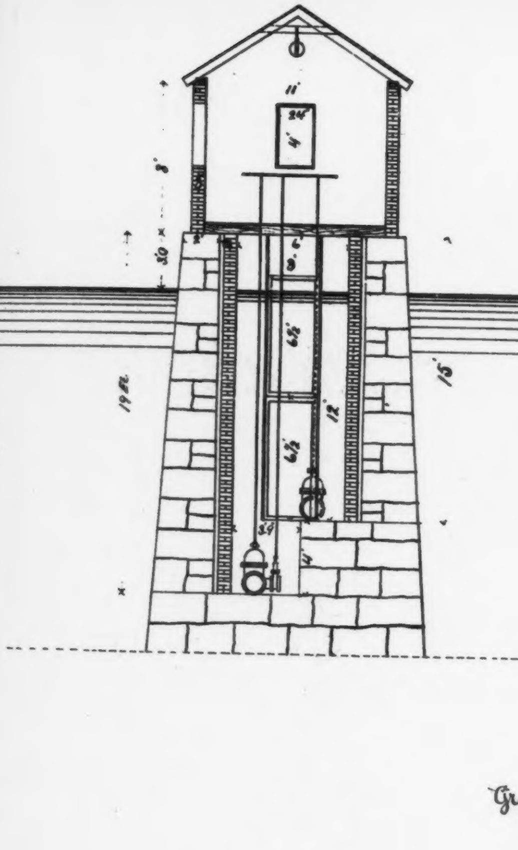
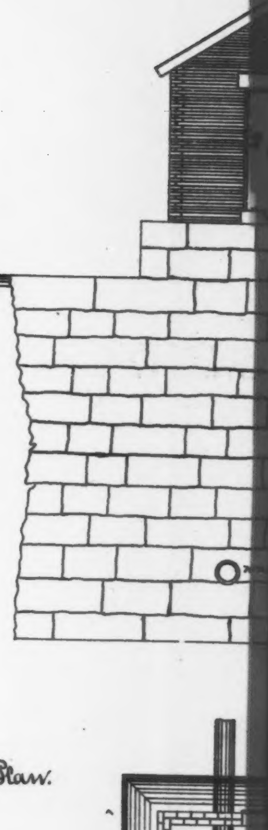
Mc KENZIE ON
SOUTHINGTON WATER WORKS.



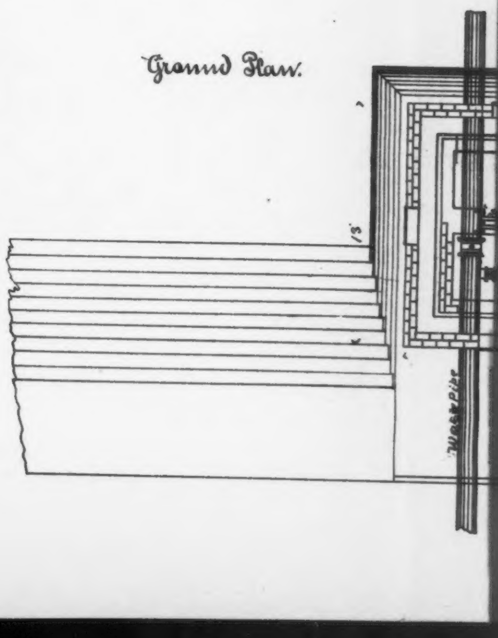
Plan of Gate House.

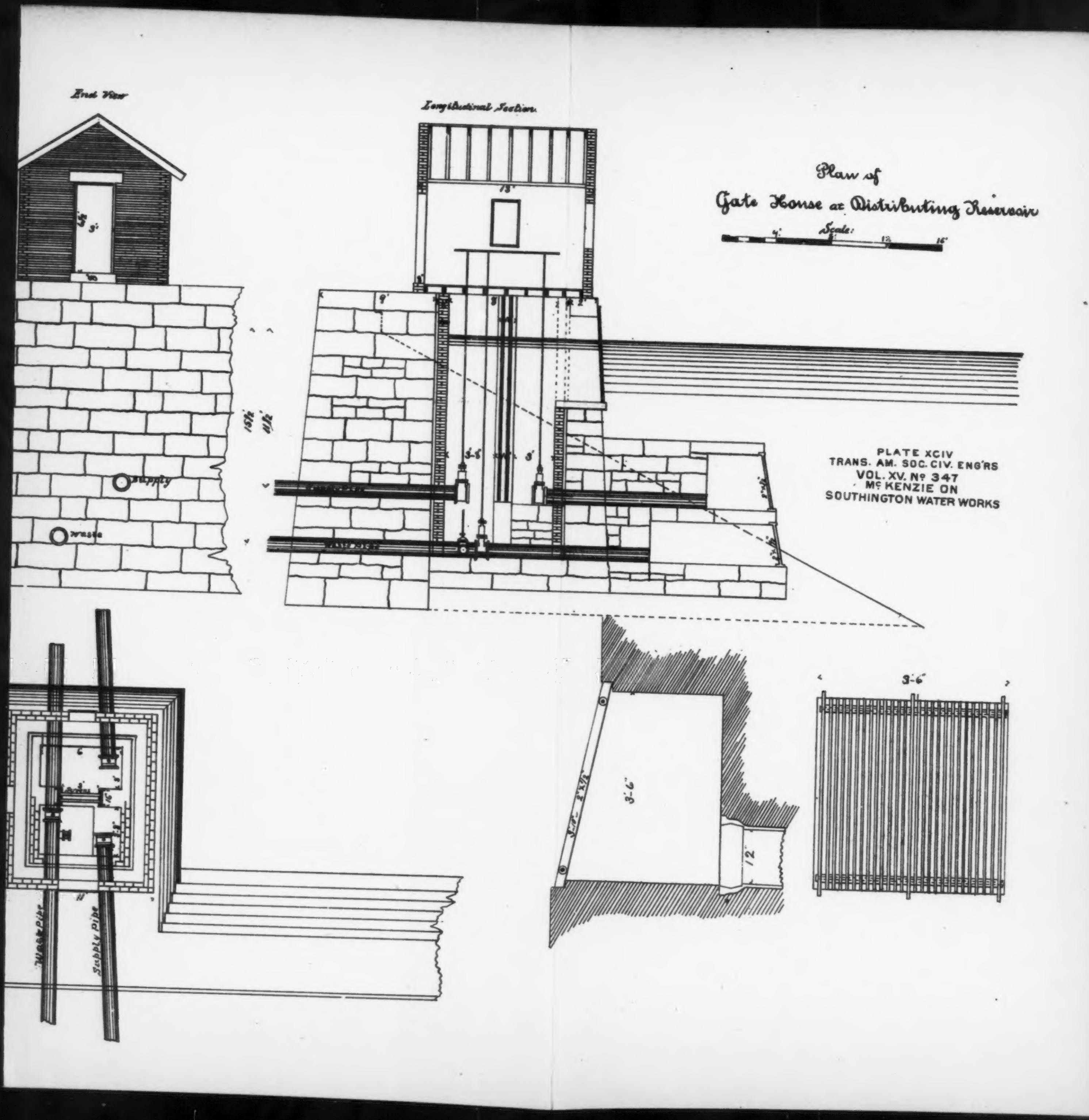
Transverse Section.





Ground Plan.




End View
Longitudinal Section
Plan of
Gate House at Distributing Reservoir
Scale:
Supply
Waste
Waste Pipe
Supply Pipe
PLATE XCIV
TRANS. AM. SOC. CIV. ENG'RS
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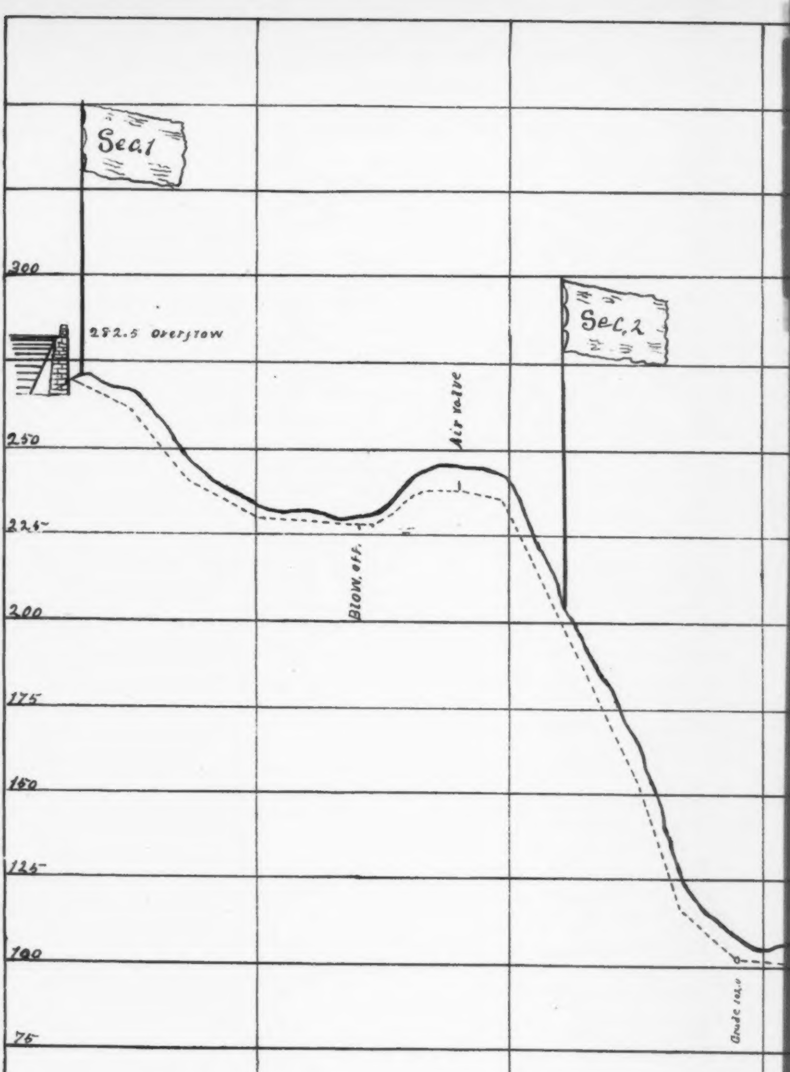
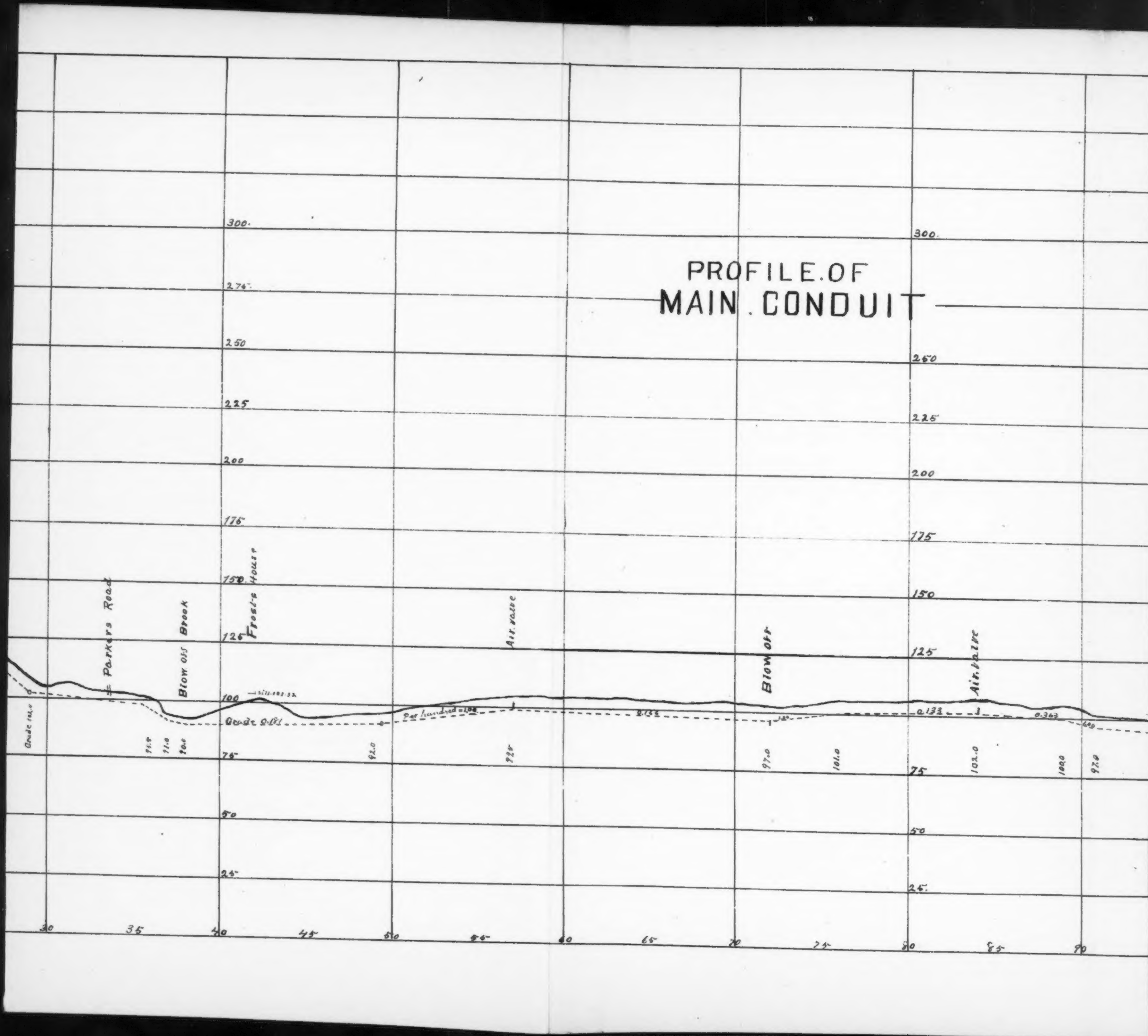


Sec. 1
Sec. 2
282.5 Overflow
Air valve
Blow off
Grade 102.0
300
250
225
200
175
150
125
100
75
50
25
0
5
10
15
20
25
30



PROFILE.OF
MAIN .CONDUIT
300.
275
250
225
200
175
150
125
100
75
50
25
Parkers Road
Blow off Brook
Frost's House
Air valve
Blow off
Air valve
Grade 0.181
Per hundred
0.133
0.363
30
35
40
45
50
55
60
65
70
75
80
85
90

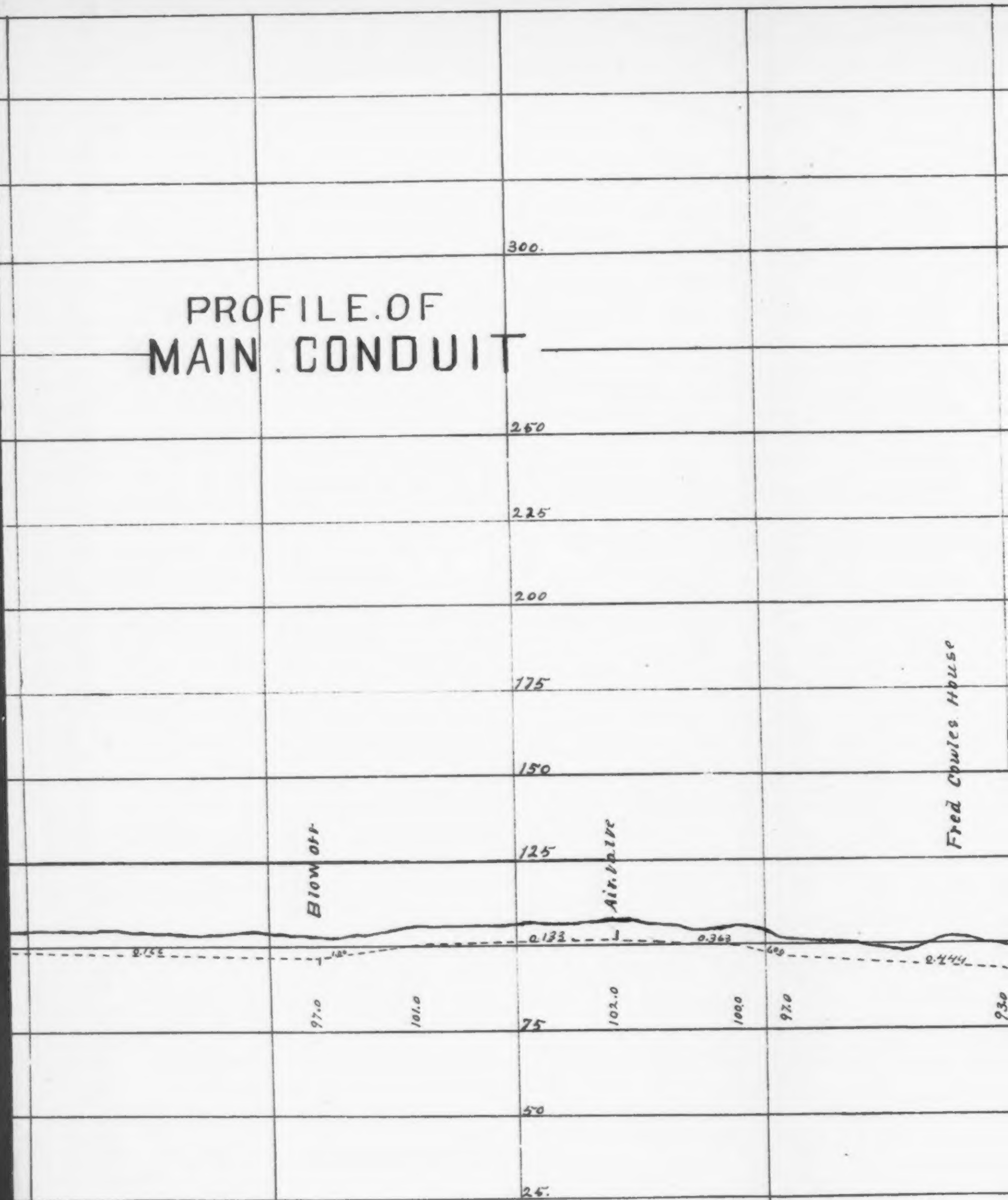

PROFILE OF
MAIN CONDUIT
300.
250
225
200
175
150
125
75
50
25.
Blow off
Air valve
Fred Cowles House
0.133
0.363
0.444
97.0
101.0
102.0
100.0
97.0
93.0
60
65
70
75
80
85
90
95

PLATE XCV.
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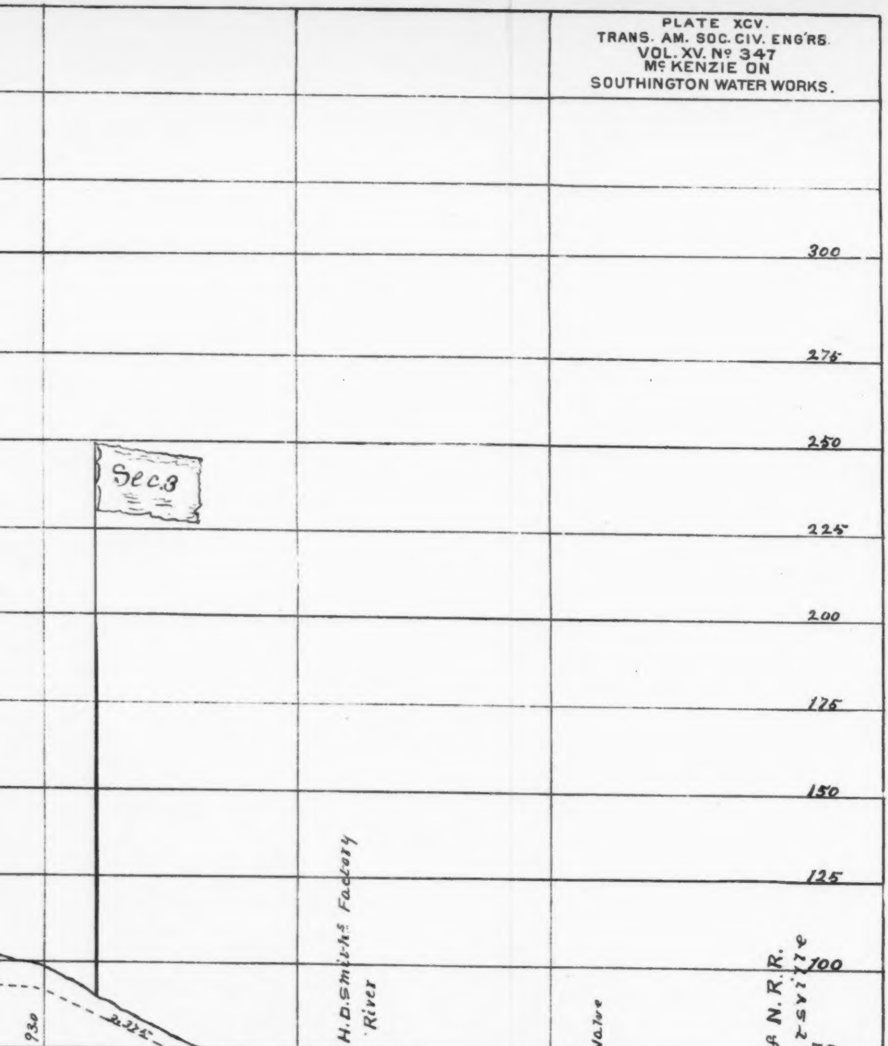
Mc KENZIE ON
SOUTHINGTON WATER WORKS.




SOUTHINGTON
PARK
6" PIPE
4" PIPE
ÆTNA NUT CO
CUTLERY CO
LUMBER YARD
DEPOT
ÆTNA MATCH CO
N.H. & N.R.R.
PECK, STOW, & WILCOX CO
QUINNIPIAC RIVER

PLATE XCVI
TRANS. AM. SOC. CIV. ENG'RS.
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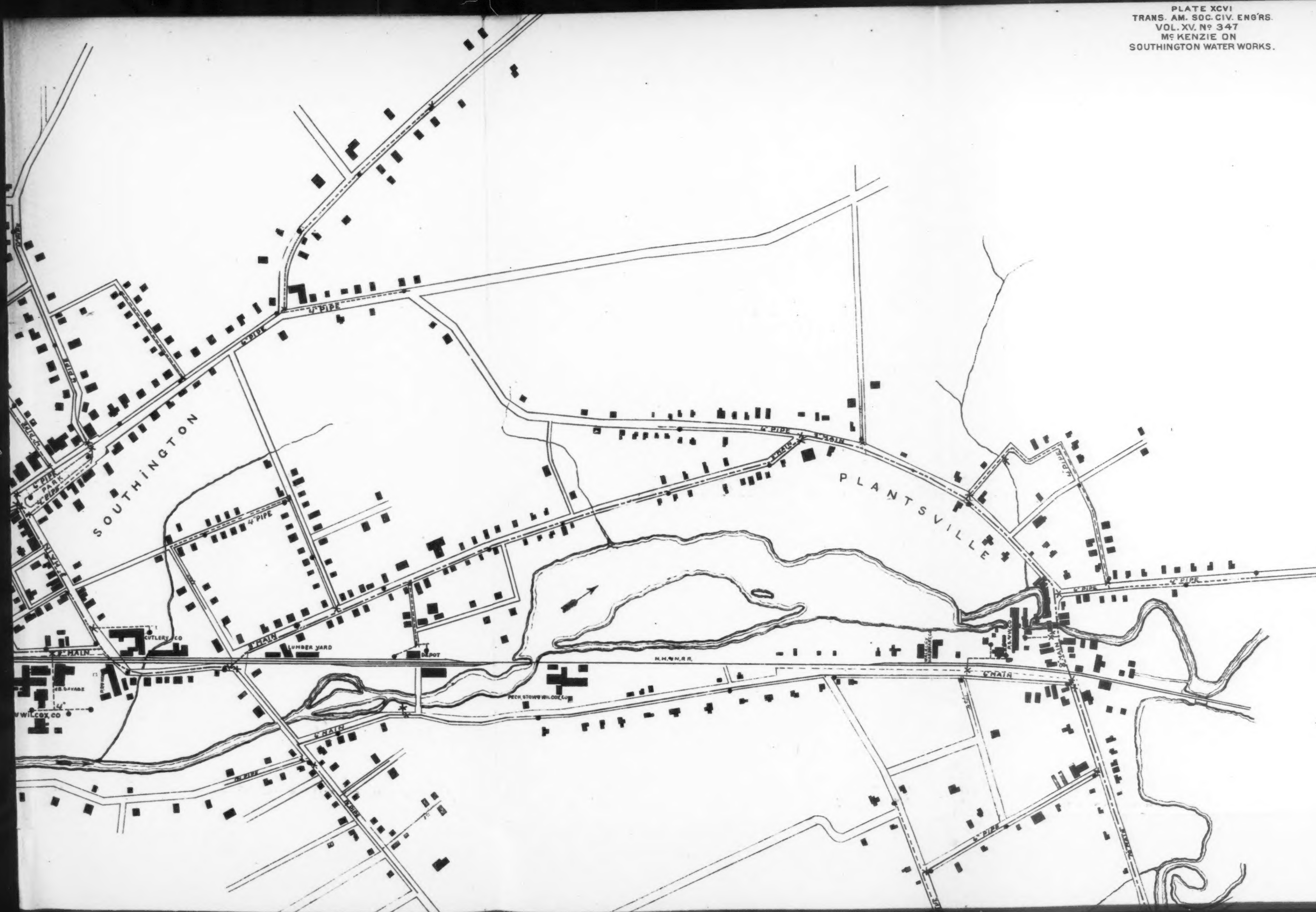
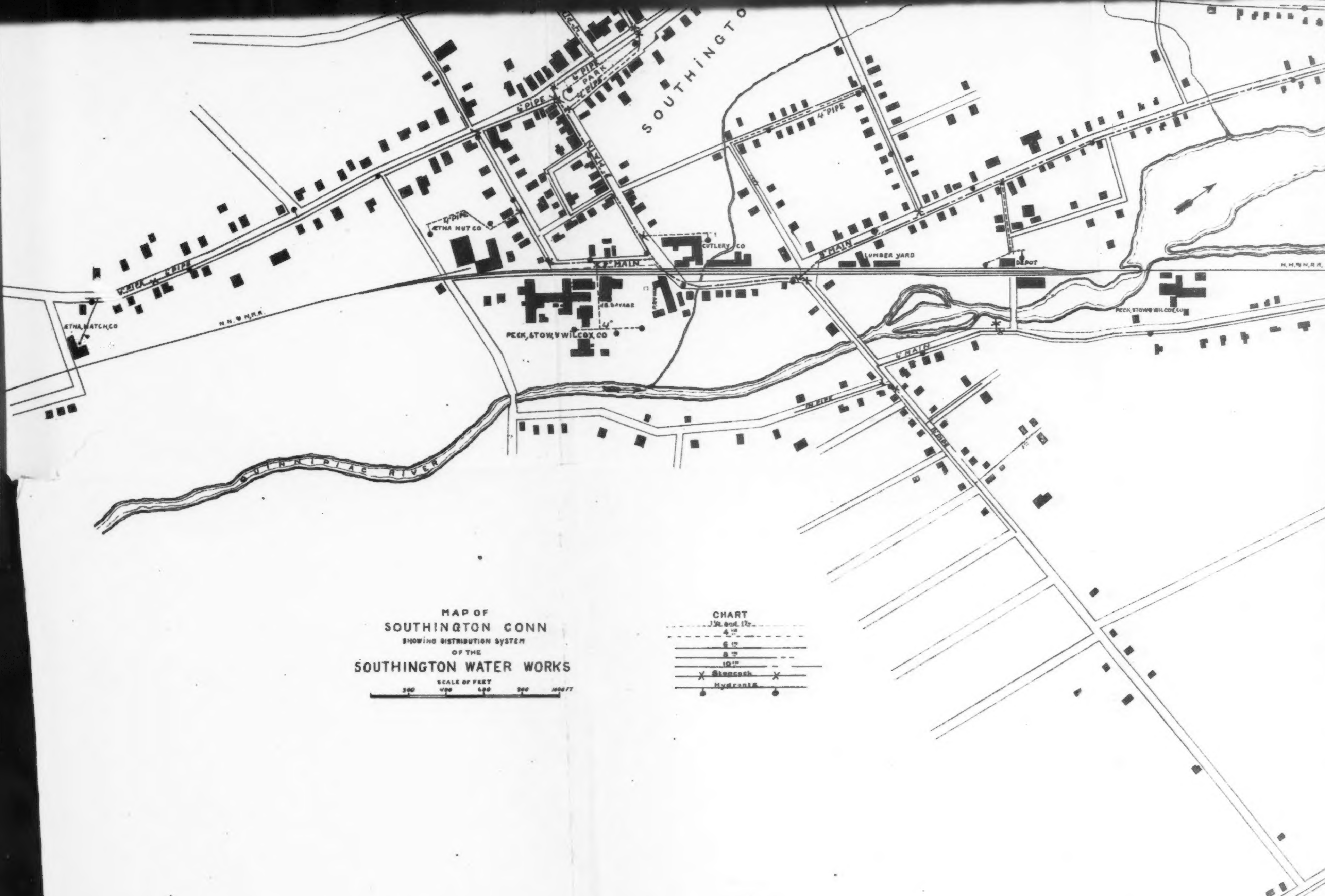
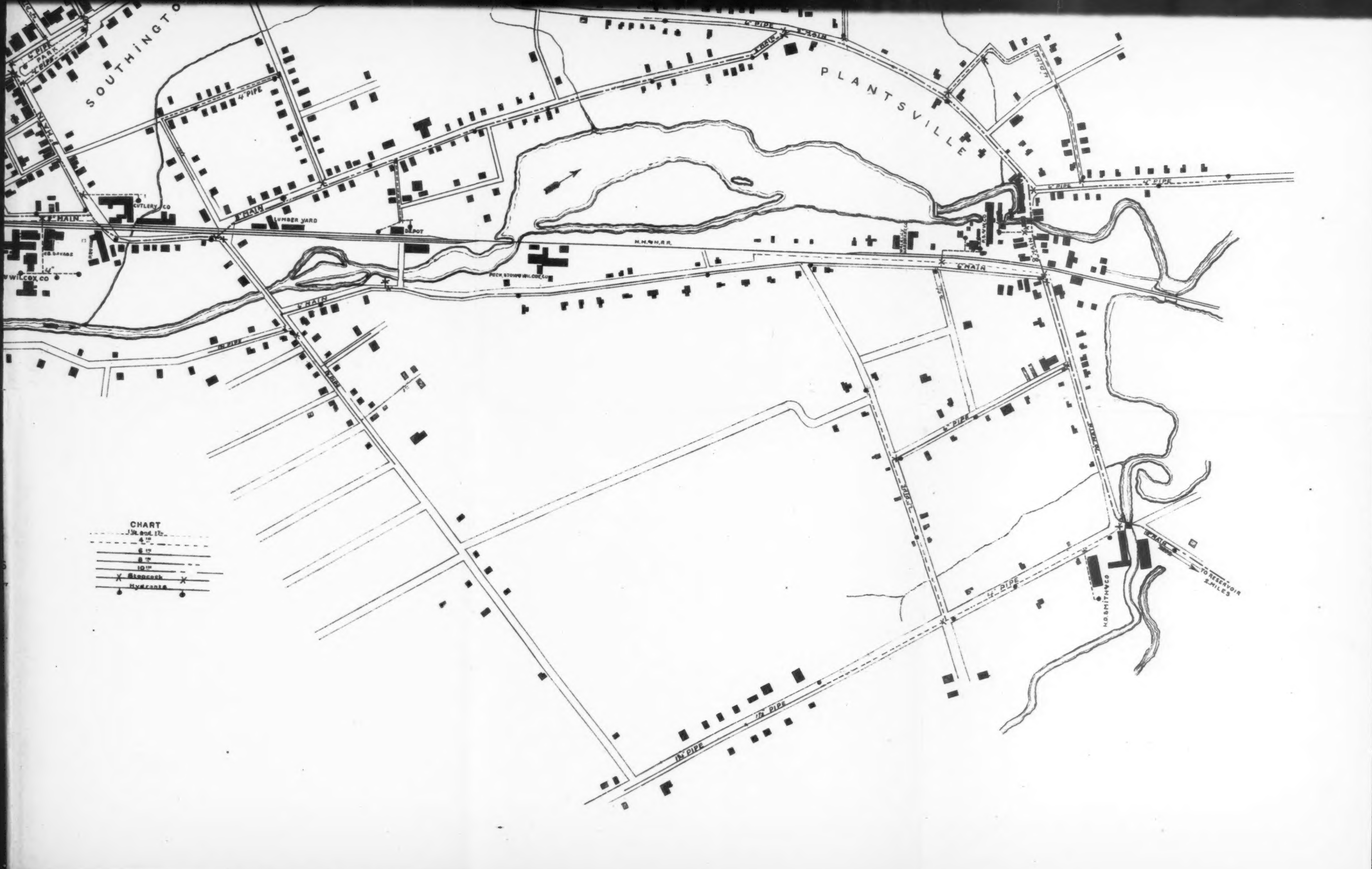
McKENZIE ON
SOUTHINGTON WATER WORKS.




MAP OF
SOUTHINGTON CONN
SHOWING DISTRIBUTION SYSTEM
OF THE
SOUTHINGTON WATER WORKS
SCALE OF FEET
200
400
600
800
1000 FT
CHART
4"
6"
8"
10"
Stopcock
Hydrants
SOUTHINGTON
QUINNIPIAC RIVER
ÆTNA WATCH CO
ÆTNA NUT CO
PECK, STOW, & WILCOX CO
CUTLERY CO
LUMBER YARD
DEPOT
N.H. & N.R.R.
4" PIPE
6" PIPE
PARK


SOUTHINGTON
PLANTSVILLE
CUTLERY CO
LUMBER YARD
DEPOT
N.H.&N.R.R.
4" PIPE
CHART
Stopcock
Hydrants
TO RESERVOIR
2 MILES
H.D. SMITH & CO

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

348.
(Vol. XV.—December, 1886.)

ERRORS IN RAILROAD LEVELS.

By HOWARD V. HINCKLEY, M. Am. Soc. C. E.

READ MARCH 3D, 1886.

The "Lists of Elevations" collated by Henry Gannett, M. E., and published in 1877 by the United States Geological Survey, contains, on page 20, a reference to the Atchinson, Topeka and Santa Fé Railroad levels, founded upon statements obtained from that road, and which reads as follows:

"On account of the character of the leveling between Topeka and Kinsley this line is valueless as a check." Corrections of 18 to 68 feet were made by Mr. Gannett upon the elevations furnished from the profiles of different parts of the road. I first noticed this in 1882, and believing that errors of such magnitude in location levels could hardly have been embodied in the construction work without being detected by either leveler or locomotive, I determined to test the correctness of our levels by carefully searching for breaks in datum planes, making the proper corrections for all parts of the line, and obtaining such checks as might be obtainable from intersecting roads and reliable benches in order to determine whether the discrepancies reported were due to the general unreliability of the levels, or to an improper report to the Government

officers of unadjusted levels; and in order to avoid, if possible, a continued confusion and doubt as to elevations of prominent points and, in fact, of nearly every station along the line.

Under authority from A. A. Robinson, M. Am. Soc. C. E., Chief Engineer, and with the very careful assistance of G. A. Lichtenberg, Draughtsman, I proceeded to compile a profile of the entire Atchinson, Topeka and Santa Fé system of roads from the Missouri River to the Gulf of California. This profile was completed January 1st, 1884, and a copy of it placed in the Society's library; it gives the corrected elevation of every station on the system, and the proper corrections to apply to the working or construction profiles for obtaining elevations above sea at any intermediate points. All elevations are in feet and decimals thereof, and are figured for the top of rail at the profile stations indicated in brackets (generally at the east end of depot), and were carried to thousandths—not to indicate that the track has been kept so truly to the original grades, but in order that the results obtained might be correct within themselves to the extent of the information at hand.

The elevations east of the continental divide are above Atlantic "mean tide," and are based upon a United States bench on the face of the south abutment of the Hannibal and St. Joseph Railroad Bridge over the Missouri River at Kansas City. The elevation of this bench was taken as 428.29 (St. Louis directrix, by James T. Gardner in "Elevations of Datum Points," 1875), plus 341.394 (furnished me by William B. Knight, M. Am. Soc. C. E., City Engineer of Kansas City, November 2d, 1882), equals 769.684.

The elevations west of continental divide are above Pacific "mean tide" at Guaymas, Sonora, Mexico, taken 0.625 below Guaymas "mean high tide" (from data furnished by T. J. Seely, M. Am. Soc. C. E., Assistant General Manager Sonora Railway, February 9th, 1883).

The following checks, Nos. 1, 2, 6 and 8, were obtained before the completion of the profile, and the others are the result of later investigation.

CHECKS.

1. Elevation carried from Kansas City to Atchison, *via* Topeka, compares with elevation taken from United States bench at Atchison, plus 0.006 feet; length of circuit, 173 miles; length of railroad levels, 116 miles.

2. Elevation carried from Kansas City to Emporia Junction compares

with elevation carried from Kansas City *via* Topeka, North Topeka and Junction City over the Union Pacific and Missouri Pacific Railroads to Emporia Junction, plus 0.180; length of circuit 196 miles.

3. Elevation carried from Kansas City, by way of Albuquerque and Atlantic and Pacific Railroad, to the Colorado River compares with Southern Pacific elevation brought from San Francisco (based upon Fort Point high water datum, and corrected, minus 1.790, from data furnished by the observer at San Francisco, October 20th, 1883), minus 2.04; length of railroad levels 2 115 miles.

4. Elevation carried from Kansas City, *via* Albuquerque, Mojave and Yuma, over the Atlantic and Pacific and Southern Pacific to Port Ysabel at the head of the Gulf of California compares with "mean tide" at that point, minus 1.03 (plus 8.90 Southern Pacific reading at Port Ysabel furnished by George E. Gray, M. Am. Soc. C. E., Chief Engineer, minus 2.04; Atlantic and Pacific difference given in check No. 3, minus 1.79; Southern Pacific correction also given in check No. 3); length of railroad levels, 2 149 miles.

5. Elevation at Pueblo crossing of Atchison, Topeka and Santa Fé Railroad, and Denver and Rio Grande Railway, compares with elevation carried from Kansas City to El Moro, thence over Denver and Rio Grande Railway, *via* South Pueblo, minus 0.580; length of railroad circuit, Pueblo, La Junta, El Moro, Pueblo, 246 miles.

NOTE A.—I have no less than six checks (?) upon Pueblo, *via* Denver, covering a range of 26 feet, and the closest result differing more than 15 feet from mine. The indefinite way in which the data for these results have been reported destroys my confidence in their reliability, especially when my El Moro check No. 5 seems to prove the correctness of my Pueblo elevations within six-tenths of a foot. Here I must quote from Gardner's "Elevations" (page 631): "I am satisfied that the important errors in our railroad and canal profiles are not so much due to imperfect instrumental work as to hasty and careless combination of the results." It would also be proper for me to state here that I have checked upon the St. Louis and San Francisco Railroad at Augusta crossing and North Wichita Junction, their elevations being carefully reported by James Dun, M. Am. Soc. C. E., Chief Engineer, and my results comparing with his at these two points, minus 7.212 and minus 7.882 respectively, elevations on both roads being based upon the same elevation of the St. Louis directrix, and these results being therefore independent of the absolute height thereof.

Also, that Mr. Frederick T. Perris, chief engineer of the California Southern, has carefully reported three checks upon the Southern Pacific Railroad as follows:

20. Elevations carried from San Diego over the California Southern Railroad to Waterman by location levels, compare with Southern Pacific elevations from San Francisco, plus 1.801.

21. Elevations carried from San Diego over the California Southern Railroad to Waterman by check levels, compare with Southern Pacific elevations from San Francisco, plus 3.684.

22. Elevations carried from San Diego over the California Southern Railroad to Colton, compare with Southern Pacific elevations from San Francisco, plus 4.058.

These three checks, combined with my check No. 3, would make my elevations, carried over Atlantic and Pacific, check upon the California Southern elevations above referred to, minus 3.841, minus 5.724, and minus 6.098, respectively; or, combining California Southern checks with my check No. 6, carrying my elevations *via* Deming, they would check upon San Diego, minus 1.863, minus 3.746, and minus 4.120 respectively. On the other hand, discarding check No. 20, at Mr. Perris' request, in favor of No. 21, made by check levels, carefully run, and combining my checks No. 6 and No. 8 with California Southern checks No. 21 and No. 22, Guaymas elevations, carried *via* Deming, compare with San Diego elevations, minus 0.356, and minus 0.730 respectively. I am unable to solve this matter satisfactorily at present, but hope to do so at some future time, along with additional checks in Kansas and Colorado, and at Texas and Mexico ports.

6. Elevation at Deming compares with Southern Pacific elevation, corrected as in No. 3, minus 0.062; length of railroad levels, 2 347 miles.

7. Elevation from Deming, carried *via* Southern Pacific and Yuma to Port Ysabel, compares with mean tide at that point (2.80, minus 1.79, minus 0.062), 0.948; length of railroad levels, 1 686 miles.

8. Elevation at continental divide (about 40 miles west of Deming, and upon a stretch of 173 miles of unconstructed line) compares with mean tide elevation brought from Guaymas, minus 3.390; length of railroad levels, 1 657 miles.

9. Elevation at Southern Pacific overhead crossing of the Atchison, Topeka and Santa Fé Railroad, near El Paso, compares with the Southern Pacific elevation at the same point brought from San Francisco, and corrected same as in No. 3, plus 0.128 (from data secured by Southern Pacific Railroad during construction), and plus 0.460 (from data secured by Atchison, Topeka and Santa Fé Railroad four years later).

NOTE B.—The Atchison, Topeka and Santa Fé determination was merely an approximate second or double check, and the difference between the two checks is due probably to the settling of the overhead trestle. The Southern Pacific check is therefore taken as reliable, and the other discarded.

10. Elevation at Deming compares with elevation carried from Albuquerque over Atlantic and Pacific and Southern Pacific Railroads, *via* Mojave, to Deming (2.04, minus 0.062), plus 1.978; length of circuit, 1 862 miles.

11. Elevation at Rincon compares with elevation carried from Rincon, *via* Deming and El Paso, crossing to Rincon, plus 0.190; length of circuit, 218 miles.

I had thought I should be doing well if I secured a transcontinental check within ten or twenty feet, or if I secured a check upon any reliable bench east of the Rocky Mountains within ten feet. The first check obtained was No. 7, and it was generally considered a remarkable coincidence, if not possibly a "manufactured" check, and I little expected to have it so closely supported by the teh other checks above given. All the old field books and profiles were searched for breaks, and all the checks here given are substantiated by documents on file in my office.

Summarizing first those lines which are all rail, or upon which level checks level, and assuming absolute accuracy in the United States levels between the Kansas City and Atchison benches, we have the following table of

RAIL CIRCUIT CHECKS.

No	From	Via	To	Miles.	Errors in feet.	Errors, feet per mile.
1	Kansas City....	Topeka.......	Atchison.......	116	0.006	0.00005
2	Emporia Junc..	North Topeka and Junction City........	Emporia Junc..	196	0.180	0.00092
5	Pueblo,........	La Junta and El Moro.....	Pueblo..........	246	0.580	0.00236
10	Deming.........	Albuquerque and Mojave.	Deming........	1 862	1.978	0.00106
11	Rincon.........	Deming and El Paso........	Rincon.........	218	0.190	0.00087

Next summarizing the checks furnished, by the assumption that the mean tide of the two coasts has a common elevation, and that Gardner's Atlantic elevation of Kansas City bench, as above given, is correct (the later levels of the Mississippi River Commission and the Coast Survey to the contrary notwithstanding), and throwing check No. 8 out of the general results, on account of the unreliability of 173 miles of unchecked preliminary mountain location levels, we have the following table of tide checks.

TIDE CHECKS.

No.	From	Via	To	Miles.	Errors in feet.	Errors, feet per mile.
3	Kansas City....	A. and P. R. R.	San Francisco..	2 115	2.04	0.00096
4	Kansas City....	A. and P. and S. P........	Pt. Ysabel......	2 150	1.03	0.00048
6	Kansas City....	Deming.......	San Francisco...	2 347	0.062	0.00003
7	Kansas City....	Deming.......	Pt. Ysabel......	1 686	0.948	0.00056
8	Kansas City....	Tombstone...	Guaymas.......	1 657	3.390	....
9	Kansas City....	El Paso.......	San Francisco..	2 459	0.128	0.00005

NOTE C.—Gardner, in his elevations of datum points, 1875 (pages 643, 644 and 653), reports errors as follows: 9.9 feet Portland to New Orleans, *via* Chicago, 2 100 miles (0.0048 per mile); 2.44 feet New York Bay to New Orleans, *via* Chicago, 1 800 miles (0.0013 per mile); 4.61 feet Raritan Bay to New Orleans, *via* Chicago, 1 800 miles (0.0025 per mile); 25.0 feet Portland to San Francisco, *via* Chicago, 3 500 miles (0.0071 per mile); 26. feet New Orleans to San Francisco, *via* Kansas City and Denver, 3 200 miles (0.0081 per mile). Mr. S. D. Mason, M. Am. Soc. C. E. Principal Assistant Engineer Northern Pacific, under date of November 19th, 1885, reports an error of "about four feet" (not yet definitely determined) from Lake Superior, at Duluth, Minn., to Commencement Bay, at Tacoma, Wyoming Territory, assuming Lake Superior elevation to be 602 feet—2 033 miles (0.00185 per mile). The correctness of my results, within the limits of my errors, are not corroborated by these errors reported from other roads, as they have no bearing upon the St. Louis directrix or any of my elevations, and are given here merely for a comparison of errors per mile.

By the close results obtained, I am convinced that the necessity for the excessive corrections applied by Mr. Gannett, arose from the elevations reported to him not having been corrected for breaks in datum planes. I do not offer my results as evidence that railroad levels in mountainous regions are generally to be depended on within one one-hundredth of an inch per mile. Nor would I intimate that the close results over these particular circuits and check lines from the Missouri River to the Pacific Ocean prove the correctness (within the limits of my errors) of the elevations of the St. Louis directrix (428.29) and Missouri River benches as established by Mr. Gardner in 1875 from Atlantic tide points. But in view of the fact that the recent levels of the United States Coast and Geodetic Survey and Mississippi River Commission tend to reduce the elevation of the St. Louis directrix thirteen and fifteen feet respectively, the results given in the second table, and based

upon Gardner's St. Louis elevations, are of special interest at this time, for to reduce St. Louis fifteen feet would be to make the "errors in feet" in my second table range from thirteen to nineteen feet.

DISCUSSION.

L. L. WHEELER, M. Am. Soc. C. E.—It may be of interest, in connection with Mr. Hinckley's paper, to give the later determinations of the elevation of St. Louis City Directrix above mean tide.

First.—By levels run under direction of the Mississippi River Commission, from Biloxi, Miss., on the Gulf of Mexico. The value of mean tide depends upon the mean of four lunations in 1882, which may yet receive a small correction. The resulting elevation for St. Louis City Directrix is 412.71 feet.

Second.—By levels run by the United States Coast and Geodetic Survey from Sandy Hook. The resulting elevation is 416.37 feet.

Third.—By levels run by United States Lake Survey to determine the elevations of the Great Lakes, and by levels run by the Mississippi River Commission from St. Louis to Chicago. The resulting elevation is 413.71 feet.

Now it is quite certain that either of the above determinations is entitled to more weight than Gardner's, and that the mean of the three is the best elevation of St. Louis City Directrix above mean tide available. This mean is 414.26 feet. This elevation is 14.03 feet less than the elevation used by Mr. Hinckley in his table of "Tide Checks." His elevation of the bench mark at Kansas City above St. Louis City Directrix should be increased, however, by 0.341 feet, making the total change in the elevation of the bench mark at Kansas City above mean tide 13.69 feet.

If the elevation of the bench mark at Kansas City be increased 13.69 feet, and it is assumed that mean tide of the Atlantic Ocean is at the same elevation as that of the Pacific, then the table of "Tide Checks" would only show large errors.

EDWARD P. NORTH, M. Am. Soc. C. E.—The discussion of long lines of levels, interesting in themselves and valuable when such care is bestowed on the comparisons, brings an equally interesting question into prominence, viz.: the relative heights of the oceans surrounding our continent. It is asserted, though not yet accepted, that the water in the Gulf of Mexico is higher than on the Atlantic coast, which is swept by the stream originating in the Gulf. Our Pacific coast is swept by the south bound portion of the North Pacific current, early utilized by the Spanish for East India trade, which, starting from about and south of the latitude of Acapulco, flows west to the Philippine Islands northwardly to the coast of Japan, and crosses to this continent as the black current or Kuro Cywa current.

It is to be hoped that either our Coast or Geological Survey will run lines of test levels from one coast to the other, as well as from the Atlantic to the Gulf, so as to determine these heights, for though ordinary railroad test leveling is sufficiently accurate for all constructive purposes, it would not, considering the distance, be satisfactory for the purpose mentioned.

Any levels connecting with points near the head of the Gulf of California should have the mean height of water determined by observations more extended than through a single lunation; as, during about half the year the prevailing winds blow into the mouth of the Gulf, establishing a persistent southward littoral current, it is said, on both shores of the Gulf. During the rest of the year the prevailing winds blow on to the shore nearly at right angles to the direction of the former winds, reversing the littoral currents and sending them to the northward, thus possibly varying the elevation of the water at Guaymas and points north of it.